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**PHASE II - COMPREHENSIVE SITE
ASSESSMENT
60 OLYMPIA AVENUE
WOBURN, MASSACHUSETTS
DEP CASE NO. 3-594
VOLUME I OF II**

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ASSESSMENT
60 OLYMPIA AVENUE
WOBURN, MASSACHUSETTS
DEP CASE NO. 3-594
VOLUME I OF II**

PREPARED FOR:
Juniper Development
Winchester, Massachusetts

PREPARED BY:
GZA GeoEnvironmental, Inc.
Newton Upper Falls, Massachusetts

December 1991
File No. 4596.2

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December 16, 1991
File No. 4596.2-C,CP
4596-C

Mr. Charles Whitten
Juniper Development
38 Holton Street
Winchester, Massachusetts 01890

Re: Phase II - Comprehensive Site Assessment
60 Olympia Avenue
Woburn, Massachusetts
DEP Case No. 3-594


Dear Mr. Whitten:

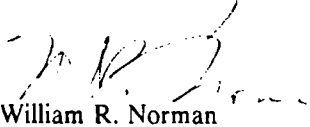
We are pleased to submit this Phase II - Comprehensive Site Assessment for the 60 Olympia Avenue site in Woburn, Massachusetts. This document was prepared in accordance with Chapter 310, Section 40.545 of the Code of Massachusetts Regulations (310 CMR 40.545), also known as the Massachusetts Contingency Plan (MCP). The work was performed in accordance with our Scope of Work dated April 14, 1989, as amended by subsequent correspondence with the Massachusetts Department of Environmental Protection (DEP).

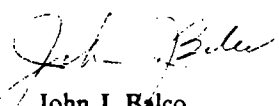
We appreciate the opportunity to assist you with this project. Please contact the undersigned if you have any questions or require further assistance.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.


Sara R. Hanna
Senior Technical Specialist


William R. Norman
Project Reviewer


John J. Balco
Associate Principal

SRH/JJB:dmh/cq
Attachment: Report

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1.00 INTRODUCTION

This report presents the results of a Phase II - Comprehensive Site Assessment, as defined by Chapter 310, Section 40.545 of the Code of Massachusetts Regulations, (CMR) of the 60 Olympia Avenue site in Woburn, Massachusetts (see Figure 1, Locus Plan). GZA GeoEnvironmental, Inc. (GZA) completed the study on behalf of the Juniper Development Group (JDG); this report was prepared in accordance with our Phase II Scope of Work dated April 14, 1989, as amended and approved by the Massachusetts Department of Environmental Protection (DEP), and is subject to the Limitations set forth in Appendix A. The Scope of Work and associated modifications are attached as Appendix B.

1.10 PURPOSE AND SCOPE

The purpose of this study was to complete a Phase II - Comprehensive Site Assessment as defined in Section 40.545 of 310 CMR 40.00, also known as the Massachusetts Contingency Plan (MCP). In general, a Phase II study is designed to further characterize the type, quantity and extent of oil and hazardous material contamination at a site, to characterize and evaluate the risk of harm that a site may pose to public health and the environment, and to provide additional data and information necessary to evaluate appropriate remedial actions at the site.

The documentation of "Phase I" issues, also in accordance with the MCP, was presented in our October 1988 report entitled "Hydrogeologic Assessment, 60 Olympia Avenue, Woburn, Massachusetts" (GZA File No. 4596.1). Additional studies conducted at and/or adjacent to the site prior to 1988 are summarized in our October 1988 report. This document, in conjunction with the October 1988 report, addresses the requirements of 310 CMR 40.545.

The scope of work for the present study included: a shallow soil gas survey; the installation of four additional shallow monitoring wells to assess the downgradient extent of a groundwater volatile organic contaminant (VOC) plume in groundwater associated with underground storage tanks at the site; the installation of two deep monitoring wells to further characterize the vertical distribution of contaminants at the site and to further characterize site stratigraphy; chemical screening of soil obtained from the newly installed wells; quantitative chemical analyses of groundwater samples from the monitoring wells and of surface water samples obtained from the Aberjona River; permeability testing at selected monitoring wells; laboratory soil gradation analyses; groundwater elevation monitoring; completion of a public health and environmental risk characterization; and the preparation of this report.

1.20 REPORT ORGANIZATION

This report presents information identified in Section 40.545 of the MCP: Phase II - Comprehensive Site Assessment. The report is presented in nine sections. Section 1.00 contains introductory material, including the purpose and scope of the study, a brief description of the site, and a brief description of Quality Assurance/Quality Control (QA/QC) procedures which were utilized throughout the course of the study. A discussion of past uses and owners at the site, as well as a synopsis of previous studies conducted at the site, and of oil and hazardous material used at the site, is presented in Section 2.00. Section 3.00 describes characteristics of the site and surrounding area, including potentially sensitive environmental receptors and local climatology. A discussion of utilities at the site is also included in Section 3.00. A description of the field work and chemical analyses performed during our current site study is presented in Section 4.00. Section 5.00 discusses the site's geology, hydrology, and groundwater flow characteristics. The results of the soil gas survey, and of chemical analyses performed on soil, groundwater and surface water samples are discussed in Section 6.00, along with a discussion of contaminant sources, transport mechanisms and fates. Section 7.00 presents GZA's characterization of potential risks to public health and the environment. Section 8.00 summarizes GZA's findings and conclusions, and Section 9.00 presents our recommendations for future actions at the site.

This study supplements information provided in GZA's October 1988 report; additional site and contaminant data are included in previous GZA reports which are discussed in Section 2.30.

1.30 QUALITY ASSURANCE/QUALITY CONTROL

A QA/QC program was developed to monitor the quality of field, laboratory and data evaluation/interpretation activities conducted by GZA personnel. The QA/QC procedures pertinent to this study are provided in Appendix C of this report.

2.00 SITE DESCRIPTION AND HISTORY

This section briefly describes the site and its history, ownership and use. Information regarding previous studies, historical use and hazardous material use are presented in other GZA reports, and are summarized in the current report.

monitoring wells B-3 and B-5 were believed to be indicative of the regional, possibly off-site, groundwater contamination problem.

2.32 Hidell-Eyster Technical Services Inc. (HET) Tank Removal Report

HET prepared a report entitled "Progress Report Relating to Underground Storage Tank Excavation, 60 Olympia Avenue, Woburn, Massachusetts," dated November 9, 1987 and describing the June 1987 removal of underground tanks from the 60 Olympia Avenue site by Craftsman Construction Corporation (CCC).

HET reported that approximately 350 cubic yards of petroleum-contaminated soil were removed from the 60 foot by 70 foot excavation during tank removal and stockpiled on and covered with polyethylene sheeting at the site. A film of floating product was observed on the groundwater in the excavation.

According to the HET report, excavation of contaminated soil was limited to prevent damage to access lanes necessary for operation of the trucking terminal. At the limit of the soil excavation, a trench and pipe system was installed. The installation is detailed in the HET report (attached to our 1988 report as Appendix B) as follows:

"Rather than causing this disruption, a trench was dug beside the southern and western portion of the pit to a depth of 12 feet. This is designed to intercept any groundwater which might be migrating away from the source of contamination and toward the Aberjona River in the event that a recovery system is deemed necessary. The trench was made approximately 5 feet from the edge of the excavation so as to leave undisturbed sediment in place. The trench was filled with gravel at its base. Four-inch slotted PVC pipe was laid on top of the gravel and connected to two 4-inch monitoring wells at two corners (MW-1 and MW-2). The pipe in the excavation was covered with gravel and then backfilled. The excavation was filled with pea gravel to a level 1 foot above static water level. A filter fabric (Mirafi) was laid over the gravel and clean fill was placed on top."

GZA personnel were not present for the tank removal or the installation of the pipe system. The approximate locations of monitoring wells MW-1 and MW-2 are presented on Figure 2.

2.33 U.S. Environmental Protection Agency (USEPA) Studies

Two Woburn municipal wells, known as Woburn Wells G and H (approximately 1,000 to 1,500 feet south of the 60 Olympia Avenue study site) were closed in 1979 due to VOC contamination. In 1983, the area surrounding the wells (including the

60 Olympia Avenue property) was named to the USEPA's National Priority List for hazardous waste site investigation under the Superfund program. USEPA and parties potentially responsible for the contamination in the area have conducted a number of studies of the area around the G and H wells to characterize the source, nature and extent of contaminants in the area, and to develop potential remedial action alternatives. These studies focused on chlorinated VOCs; petroleum constituents (e.g. benzene, toluene, xylenes, ethyl benzene, and related compounds) were not found to be widely distributed in the area surrounding Wells G and H.

The studies conducted by EPA and others will not be described in detail in this report, although regional information regarding contaminant distribution and hydrogeology will be presented in subsequent sections.

In 1989, EPA issued a Record of Decision (ROD), presenting the remedial alternative selected for the site. The ROD calls for recovery and treatment of contaminated groundwater at identified source areas, removal of contaminated soils, and additional study of contaminants in the central portion of the G and H Superfund site. EPA identified five source areas for the groundwater contamination detected at the G and H site:

- Unifirst Corporation, at 15 Olympia Avenue, to the northwest of the 60 Olympia Avenue property;
- W.R. Grace Cryovac Division at 369 Washington Street, approximately 2,000 feet northeast of the study site;
- the Wildwood Conservation Corporation property (formerly known as the John J. Riley Tannery or Beatrice property) to the southwest of the site;
- the Olympia Nominee Trust property at 60 Olympia Avenue (this is the portion of the 60 Olympia Avenue property located on the west side of the Aberjona River; EPA detected chlorinated VOCs in groundwater in the southern portion of this property); and
- the New England Plastics property on Salem Street to the southeast of the study site.

Additional studies are currently underway in preparation for the design and installation of groundwater treatment systems and the excavation of contaminated soils.

EPA is not currently planning remedial activities on the portion of the 60 Olympia Avenue property east of the Aberjona River (subject of the current report).

GZA personnel located two monitoring wells, B-2A and B-3A, on the subject site; Juniper Development had no information concerning the installation or purpose of these two wells, but believed them to be part of the USEPA study (see Figure 2). GZA notes that these wells are not included on plans of the G and H site developed by EBASCO Services Incorporated¹ as part of its studies of the wells G & H site for the EPA.

2.34 GZA's 1988 Hydrogeologic Assessment

GZA was retained by Juniper Development on February 19, 1988 to evaluate the extent of groundwater contamination detected during tank removals at the site in June 1987 and during subsequent groundwater sampling at the site in November 1987. The study was requested by the DEQE.

GZA's 1988 study included a review of underground storage tank history at the site; a review of previous environmental studies conducted at the site; a subsurface exploration program in the form of test borings and six monitoring well installations; chemical screening of soil and groundwater samples for VOCs from the newly installed borings (GZ-1 through GZ-6), of groundwater from existing monitoring wells and of two surface water samples; quantitative analyses for petroleum hydrocarbons of groundwater samples from selected monitoring wells; an evaluation of subsurface conditions, gauging of all monitoring wells at the site for the presence of free-phase petroleum product; and a leveling survey to establish groundwater elevations and local groundwater flow direction at the site.

GZA screened soil samples from borings GZ-1 through GZ-6 for VOCs using an H-Nu Model PI-101 photoionization analyzer with a 10.2 eV lamp. The H-Nu screening results ranged between 0.1 and 35 parts per million (ppm), referenced to a benzene standard, and indicated the presence of VOCs in the soils near and below the water table in the area of the four underground storage tanks and their associated pump islands (GZ-1 and GZ-3). Soil samples GZ-1/S-3 and GZ-3/S-2 exhibited H-Nu readings of 21 and 35 ppm, respectively. H-Nu screening results on soil samples from borings GZ-2, GZ-4, GZ-5 and GZ-6 were less than 2.8 ppm, which was considered background; all but one of the samples indicated VOC concentrations of 1.0 ppm or less.

¹EBASCO Services, Inc., "Final Supplemental Remedial Investigation for Feasibility Study Wells G and H Site, Woburn, Massachusetts", EPA Work Assignment Number 132-IL46, EPA Contract Number 68-01-7250, December 1988.

Screening of soil samples GZ-1/S-3 and GZ-3/S-2 using a gas chromatograph (GC) identified methyl-t-butyl ether (MTBE) at 3.6 ppm in both samples and toluene (0.15 ppm), ethylbenzene (0.18 ppm), m,p-xylenes (0.08 ppm) and o-xylene (0.09 ppm) in sample GZ-1/S-3. The detection of these VOCs indicated the presence of gasoline constituents in soil samples GZ-1/S-3 and GZ-3/S-2; the proportion of MTBE detected further indicated an unleaded variety of gasoline. None of the 23 common VOCs identified by GZA's GC screening methods was detected in soil sample GZ-4/S-1.

VOC screening of groundwater samples collected from wells GZ-1, GZ-3, MW-1 and B-2A identified elevated levels of MTBE and benzene, toluene, ethylbenzene, and xylenes (BTEX compounds) which, as previously noted, are commonly associated with the presence of unleaded gasoline. GC screening also identified trace levels of toluene and benzene in samples from monitoring wells B-4 and GZ-2, respectively. Benzene was reported at levels below GZA's laboratory detection limit in the sample from monitoring well MW-2.

GC screening also identified a low level of the chlorinated VOC tetrachloroethene (PCE) in the groundwater sample obtained from monitoring well B-3A. Other than normally occurring methane, no VOCs were detected in groundwater samples from GZ-4, GZ-5, GZ-6, B-1, B-5 or in the Aberjona River surface water samples SW-1 and SW-2.

Based on the groundwater GC screening results, groundwater samples from MW-1 and GZ-4 were submitted for petroleum hydrocarbon (PHC) Fingerprinting analysis by ENSECO Environmental Analytical Laboratories of Cambridge, Massachusetts. The results of the fingerprinting analysis identified a total of 3,500 ppm of moderately weathered No. 2 fuel oil in the sample from MW-1, while no PHCs were detected in the sample from GZ-4.

Based on the results of screening and analysis of groundwater samples, GZA noted that groundwater contamination appears to extend south and west from the underground storage tank area toward the Aberjona River. In addition, GZA noted that an elevated level of VOCs found in well GZ-1 (located approximately 40 feet northwest from the fuel pump islands) could indicate another source of contamination, such as overfilling of vehicles or leaks from fuel lines.

General subsurface conditions at the site encountered during GZA's 1988 study consisted of 6 to 8 inches of asphalt over 3 to 7 feet of fill material overlying natural peat, sand and gravel. The fill was generally found to overlie 3 to 7 feet of sand or silty sand, and at one boring location, GZ-4, 3.5 feet of peat. The six borings encountered a dense sand and gravel at depths between 9 and 12 feet; each boring was terminated in the sand and gravel. In boring GZ-1, peat was encountered at 9 to 12 feet, underlying fill and sand before augering into sand and gravel at 12 feet.

A floating petroleum product thickness of between 1 and 6 inches was detected in monitoring well MW-1 at different times during GZA's 1988 study. Monitoring well GZ-3 exhibited a floating petroleum layer of less than 1/4 inch on July 5, 1988; petroleum product was not detected during GZA's previous measurements of this well. GZA did not detect free-floating petroleum product in the other monitoring wells on site.

During GZA's 1988 study, the depth to groundwater at the site varied from 3.4 to 7.2 feet below the ground surface. An interpretation of local groundwater flow at the site using groundwater depth and wellhead survey data, indicated that groundwater flow direction at the site was generally to the southwest. This was consistent with the assessment of regional flow direction presented in studies conducted by EPA in association with the Wells G and H Superfund site.

GZA anticipated that sewer lines along the northwestern portion of the site may influence the groundwater flow direction and movement of residual contamination at the site, and that other utilities and building structures may create complex localized groundwater flow conditions. Existing data at the time of GZA's 1988 study was insufficient to fully characterize the effects of these features on flow at the site.

Based on the work conducted in 1989, GZA presented the following recommendations for additional work at the site:

- A. Remove free-floating product which was detected in monitoring wells MW-1 and GZ-3.
- B. Install additional monitoring wells to assess whether the reported contamination in monitoring well B-4 is associated with tanks located on site or from another source.
- C. Institute a groundwater monitoring program to evaluate water quality over time at the site borders.

GZA also recommended that additional studies or remedial action at the site should be coordinated with EPA studies of the subject site.

2.40 OIL AND HAZARDOUS MATERIALS USE

GZA conducted a tour of the interior of the site building as part of our 1985 study; the interior of the facility was visited again in 1989. Observations made during our 1989 site visit are summarized below. In general, hazardous materials and oil used at the site during the current study are similar to those observed in 1985.

As noted previously, the facility was occupied by several trucking firms and by a U.S. Customs office. One tenant, Nunes Brothers Trucking and Warehouse, stores and distributes chemicals; according to trucking firm employees, these chemicals are not manufactured or repackaged on-site. GZA observed some spillage from containers in the warehouse area.

United Truck Leasing leases trucks and provides maintenance in a garage on site. Typical materials associated with the operation and maintenance of trucks (antifreeze, motor oil, diesel fuel, waste oil) are present in the United Trucking Leasing area. United Truck Leasing is registered as a very-small quantity generator of hazardous waste under the Federal Resource Conservation and Recovery Act (RCRA). APS Truck Service operates a truck repair facility at the site; materials present at APS are similar to those noted at United Truck Leasing.

Neither of the remaining tenants, Roadway Package Systems (RPS) nor the U.S. Customs office, use oil or hazardous material in their routine operations, although containers of various chemicals seized by Customs agents are sometimes present.

3.00 PHYSICAL CHARACTERISTICS OF SITE AND SURROUNDING AREA

3.10 PRESENT SITE CONDITIONS

As noted in Section 2.00, the study site consists of approximately 7 acres of land adjacent to and along the east bank of the Aberjona River. The land is occupied by a one-story brick building and an associated paved parking lot. The site is presently utilized as a trucking terminal with a portion of the building being occupied by a U.S. Customs office. Trucking terminal lessees are identified in Section 2.00.

At the times of GZA's visits to the site, GZA observed various trucking terminal activities including loading and unloading, vehicle repair and routine maintenance, including diesel filling and vehicle washing. One active diesel pump island and one abandoned gasoline pump island, and two truck washing bays are located on the west and south sides, respectively, of the portion of the building occupied by United Truck Leasing. Vehicle washing was done with a steam-cleaning machine which was located inside of the maintenance garage.

In March 1990, a United Truck Leasing employee informed GZA that all truck washing activities had been suspended by property owner Charles Whitten until further notice. Prior to the suspension of truck washing at the site, runoff discharged into a parking lot where, on several occasions, GZA observed soap, dirty, oily-looking water ponded on the parking lot surface. GZA anticipates that at least a portion of this

runoff eventually infiltrated through cracks in the pavement. GZA did not observe storm drain catch basins on this portion of the parking lot.

Remaining portions of the paved parking lot were used for employee and truck parking. GZA observed minor amounts of trash consisting primarily of paper and cans scattered along the edges of the parking lot on all sides of the site.

The wetlands located beyond the paved parking area to the east, south and west of the site are described in more detail in Section 7.40 of this report. During GZA's March 15, 1990 visit to the site, a milky-orange substance was observed to be pooled in three small pits in the wetlands along the southeast side of the site, within approximately 20 feet of the paved parking lot. The material did not emit an odor or have a readily apparent source. During the same visit, GZA noted an odor resembling esters (a sweet, organic compound odor) emanating from the wetlands located on the far southern portion of the site; GZA did not identify a source for this odor.

3.20 NEARBY SURFACE WATER RESOURCES

The Aberjona River flows for approximately 16 miles north to south from its source in Reading, Massachusetts, to its eventual discharge point in the Boston Harbor. Between Reading and the Boston Harbor, the Aberjona River discharges into the Mystic Lakes, which in turn form the Mystic River which discharges into the Amelia Earhart Dam in Somerville. At the Somerville dam, the Mystic River meets with the Chelsea River and continues to flow toward the Boston Harbor.

The Aberjona River splits the 60 Olympia Avenue property into two sections; it forms the western boundary of the Phase II investigation portion of the property. The river splits into two channels just south of the study site's southern boundary, and the two channels converge approximately 1,000 feet further downstream.

The Massachusetts Division of Water Pollution Control currently classifies the entire length of the Aberjona River as a Class B river, designated for the uses of protection and propagation of fish, other aquatic life and wildlife and for primary and secondary contact recreation. The portion of the Aberjona River in the vicinity of the site is designated as a warm water fishery; a spokesperson for the Division of Fisheries and Wildlife expressed doubt that any fish actually live in the Aberjona River.

Water quality problems identified in the Aberjona River include ammonia, dissolved oxygen, coliform bacteria and metals. Three unconfirmed point sources of these contaminants are storm sewers, surface runoff and highway maintenance and runoff; industrial land treatment was listed as a confirmed point source of contamination

observed in the river. The Aberjona River in the vicinity of the site does not currently support the Class B designation.²

The nearest public water supply is Horn Pond located over 2 miles to the southwest of the site. No active public or private water supply wells in the vicinity of the site were noted in our current research.

3.30 FLOODING POTENTIAL

According to the City of Woburn Flood Insurance Rate Map (Panel 250229-0003B, effective July 2, 1980), the central portion of the site occupied by the existing building and paved area lie within Zone C, areas of minimal flooding. Portions of the site occupied by the Aberjona River and associated wetlands lie with Zone A-2, "areas of the 100-year flood where base flood elevations and flood hazard factors have been determined"; and within Zone B, "areas between the limits of the 100- and 500-year floods or certain areas subject to 100-year flooding with average depths less than 1 foot or where the contributing drainage area is less than 1 square mile; or areas protected by levees from the base flood." Base flood elevations for the A-2 zone at the site are between 47 and 49 feet, referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

3.40 WETLANDS AND CRITICAL HABITATS

As previously noted, the study area lies within the Aberjona River basin which is a sub-basin of the Mystic River Watershed. One of the major wetland areas in the Mystic River Watershed in Woburn is the wetland located along the Aberjona River which helps to store excess runoff during flood conditions and gradually releases this water to streams during dry periods. This wetland was substantially larger at one time; however, extensive development and paving in the area and filling along the edges have decreased the size of the wetland.

The U.S. Department of the Interior National Wetlands Inventory map for the study area (Lexington, Massachusetts Quadrangle) classifies the Aberjona River in the vicinity of the site as an emergent deciduous shrub swamp (east of the trucking terminal) and palustrine broad-leaved deciduous forest (red maple swamp) to the west and south of the site.

The portion of the Aberjona River watershed in the vicinity of the site is not considered a Priority Wetland by the USEPA within the Specific Listings for this

² Massachusetts Department of Environmental Protection, Division of Water Pollution Control, "The Commonwealth of Massachusetts Summary of Water Quality, Appendix IV - Non-Point Source Assessment Report" 1989.

region. However, all wetlands adjacent to or between Routes 128 and 495 are considered Priority Wetlands in the General Listings, due to development pressure on property in this area. The subject site is not located between Routes 128 and 495, but it is approximately 500 to 1,000 feet south of Route 128.

According to the Massachusetts Natural Heritage and Endangered Species Program's 1989 Atlas of Estimated Habitat of State-Listed Rare Wetlands Wildlife, no state-listed rare wetlands wildlife habitat is present in the vicinity of the site. However, the state-listed invertebrate Mystic Valley Amphipod (Crangonyx aberrans) has been reported along other portions of the Aberjona River by Alliance Technologies Corporation.³

The Massachusetts Division of Fisheries and Wildlife lists 27 fish species in the Aberjona River basin, of which the 13 most abundant species are:

<u>Common Name</u>	<u>Scientific Name</u>
Alewife	<i>Alosa pseudoharengus</i>
Pumpkinseed	<i>Lepomis gibbosus</i>
Bluegill	<i>Lepomis macrochirus</i>
American eel	<i>Anguilla rostrata</i>
Yellow perch	<i>Perca flavescens</i>
Goldfish	<i>Carassius auratus</i>
Golden shiner	<i>Notemigonus crysoleucas</i>
Brown bullhead	<i>Ictalurus nebulosus</i>
White perch	<i>Morone americana</i>
Largemouth bass	<i>Micropterus salmoides</i>
Swamp darter	<i>Percidae spp.</i>
Chain pickerel	<i>Esox niger</i>
Common carp	<i>Cyprinus carpio</i>

No fish were observed in a limited investigation of the river and associated marsh performed by Alliance.⁴

³Alliance Technologies Corporation, "Wells G and H Wetland Assessment", March 1986, USEPA Contract No. 68-01-703.

⁴ ibid.

3.50 CLIMATOLOGY

The climate of the Woburn area may be described with meteorological data collected at the National Weather Service Office at General Logan International Airport in Boston, Massachusetts. The airport is located approximately 10 miles southeast of the 60 Olympia Avenue site.

The annual average precipitation at Boston for the period 1941 through 1980 was 42.52 inches with amounts ranging from as low as 23.71 inches in 1965 to as high as 62.32 inches in 1954. A maximum 24-hour value of 8.40 inches occurred in August 1955.

The first measurable snowfall of winter usually occurs at the end of November, and the last snowfall in spring is generally near the middle of March. The average annual snowfall is 42 inches, with amounts ranging from as low as 10.3 inches in 1972-1973 to as high as 89.2 inches in 1947-1948. A monthly maximum snowfall of 41.3 inches occurred in February 1969.

The mean annual temperature is about 50°F, but seasonal variations bring tropical warmth of over 90°F in the summer and polar cold of sub-0°F in winter. The coldest months are January and February, averaging about 29°F. The record minimum temperature of -12°F was recorded in January 1957. July and August average near 70°F, with a record maximum temperature of 102°F recorded in July 1977.

The annual average hourly wind speed is 12.7 miles per hour. Calm conditions are infrequent (0.3 percent). Wind speeds are highest during the winter, reflecting the increase in the frequency of intense storms affecting New England. Wind speeds are lowest during the summer, which is the period that lacks organized large-scale storm activity, although high wind gusts can occur during this season as a result of localized thunderstorm activity.

3.60 UTILITIES

The site is served by municipal water and sewer, is heated by natural gas and is also connected to electrical and telephone service. Utility lines are shown on Figure 2.

Information available at the Woburn Water Department indicated that the 60 Olympia Avenue property received municipal water service in 1963. Engineering Department records indicated that municipal sewer service was provided to Olympia Avenue between 1960 and 1962, but no date was specified for sewer connection to the 60 Olympia Avenue property. Note, however, that sewer service was available on Olympia Avenue prior to the construction of the site building in 1963.

GZA obtained copies of two plans from the Woburn Engineer's Office showing sewer layouts at and in the vicinity of the site; these plans are dated November 1960 and December 1984. According to the 1984 sewer plan, a 12-inch municipal sewer line runs east to west along Olympia Avenue to the north of the site. Approximately in line with the northwest corner of the 60 Olympia Avenue building, the 12-inch sewer line is connected to a 18-inch vitrified clay sewer line, which is contained in a 20-foot-wide easement and trends northeast-southwest beneath the northwest corner of the site. The 1984 plan indicates that the 18-inch sewer line runs beneath the Aberjona River and is connected to a 24-inch north-south trending City sewer line approximately 300 feet to the west of the property. A 42-inch Metropolitan District Commission (MDC) sewer line runs parallel to and adjacent to the east of the 24-inch sewer line; both lines are contained in 20-foot-wide easements.

According to the 1960 sewer plan, the burial depth of the base of the 18-inch sewer line ranges between approximately 4 to 8 feet below ground surface on the northwestern portion of the property and in the vicinity of the Aberjona River. The 1960 sewer plan indicates that the base of the concrete sewer easement is set at approximately 4 feet below ground surface; the plan indicates that this depth corresponds to the base of a peat layer in the vicinity of the Aberjona River. Based on measured groundwater depths in the vicinity of the northwestern portion of the site, the sewer line lies between approximately 1 to 3 feet below the groundwater table.

Information regarding the two sewer lines to the west of the site was obtained from Volume XIII of the Wells G and H National Priorities List Administrative Record (Appendix B History of Pollution in Woburn, Massachusetts, 1989). Available information indicated that the 24-inch sewer (East Side Interceptor Sewer) was constructed in the early 1900s, and the 42-inch MDC sewer (MDC Wilmington Trunk Sewer) was constructed in 1961. The Administrative Record identified both sewer lines as possible sources of contamination to the overburden aquifer in the vicinity of the site since both sewers are known to overflow in the vicinity of Salem Street and Olympia Avenue, and both sewers are known to "surcharge" as a result of greater pressure heads inside versus outside of the pipes.

Available information did not indicate the burial depths of water, gas, telephone or electric lines at the site; however, details on the 1984 sewer plot plan indicate that the water, gas, sewer and electric lines are connected to the north side of the site building from Olympia Avenue (see Figure 2).

4.00 FIELD EXPLORATION PROGRAM

To further assess groundwater flow characteristics and soil and groundwater contamination at the site, GZA's Phase II field program included: a shallow soil gas

survey; the execution of six additional borings and installation of six monitoring wells; field and laboratory permeability testing of soils; and sampling and laboratory analyses of groundwater, surface water and soil from the site.

4.10 SITE HEALTH AND SAFETY PLAN

Prior to performing the field studies described below, a health and safety plan was developed and reviewed by GZA personnel. Field monitoring and personal protective clothing/equipment were selected based on current site use and features, analytical data collected during our previous site studies, and on potential hazards associated with installing soil gas probes and drilling. The project Health and Safety Plan is attached as Appendix D.

4.20 SHALLOW SOIL GAS SURVEY

A soil gas survey was conducted as a screening technique for assessing the nature and extent of VOCs in the site soil and/or groundwater. Soil gas data were collected to further evaluate the areal distribution of VOCs at the site, and to aid in the selection of additional boring locations.

On July 13 and 14, 1989, GZA personnel collected and field-screened 29 shallow soil gas samples from the site. Twenty-three soil gas monitoring points were installed in a generally rectangular grid pattern in the vicinity of the underground tanks at the site. The pattern was designed to further delineate the extent of petroleum-related compounds in the area and to identify additional sources of VOCs, if present. Six additional soil gas monitoring points were installed in the vicinity of monitoring well B-4, where trace concentrations of toluene and benzene had been detected in the groundwater during GZA's 1988 study. Soil gas sampling locations are shown on Figure 3.

Soil gas samples were obtained by driving a 4-foot probe into the soil with a vibratory hammer to a depth of about 3 to 3.5 feet. The probe was jacked up 6 inches and a 3/16-inch-diameter solid stainless steel rod was inserted into the probe to release the disposable tip at the bottom of the probe and allow the collection of soil gas from this point at the bottom of the probe. A pump connected to a three-way valve sampling head at the top of the probe evacuated air at a rate of 1 liter/minute from the soil to an H-Nu Model PI-101 photoionization analyzer (H-Nu). The soil gas was screened with the H-Nu until a maximum measured concentration of VOCs being evacuated from the soil stabilized. A sample for gas chromatographic analysis was obtained from the probe via a direct syringe hook-up on the three-way valve sampling head. The probe was rinsed with distilled water after each sample and ambient air was run through the pump in order to avoid cross-contamination.

GZA's soil gas survey report is attached as Appendix E; a copy of this report was sent to the DEP in October 1989.

4.30 TEST DRILLING AND SOIL SAMPLING

On January 2 through 8, 1990, a total of six test borings (GZ-7 through GZ-12) was completed at the site by GZA Drilling, Inc. of Brockton, Massachusetts. A truck-mounted rotary drill rig was used to complete the test borings. Boring locations are shown on Figure 2.

Boring locations were selected to permit soil and groundwater sampling from areas downgradient of potential sources of contamination based on a review of previous study results. Four shallow test borings (GZ-7 through GZ-10) were conducted in the downgradient vicinity of the underground waste oil and diesel fuel tanks to assess the areal extent of soil and groundwater contamination by BTEX compounds, which had been identified during GZA's soil gas survey (see Appendix E).

As described in the Work Plan dated April 14, 1989 and the soil gas survey report dated October 18, 1989, two deep borings were to be installed at the site, with the locations to be determined following screening and analysis of soil samples from the new shallow borings. The deep borings were to be installed adjacent to the shallow borings where the highest levels of VOCs were detected. However, as described further in Section 6.20 below, elevated levels of VOCs were not detected in soil from the new shallow borings. Deep borings GZ-11 and GZ-12 then were conducted downgradient of the underground diesel storage tanks and waste oil tank, respectively, as shown in Figure 2. GZA obtained verbal approval of these locations from Ms. Rodene DeRice of DEP during the drilling program in January 1990.

Shallow borings GZ-7 through GZ-10 were advanced by 3-3/4-inch-diameter hollow stem auger techniques without the use of water or other drilling fluids; these borings were terminated in natural sand at depths ranging from 13 to 17 feet below ground surface. Deep borings GZ-11 and GZ-12 were advanced by both hollow stem auger techniques and by spinning 3-inch-diameter casing. Casing advancement, used to prevent blowing sands and hole collapse, was begun in both borings at approximately 30 feet below ground surface or at approximately 10 feet into the silty sand horizon. Approximately 70 gallons of water obtained from the City of Woburn municipal supply was added to each of the deep boreholes during drilling operations to facilitate casing advancement. Refusal was encountered in borings GZ-11 and GZ-12 in till at 63 and 66 feet below ground surface, respectively, presumably at the top of bedrock.

Soil samples were collected from each of the six borings at 5-foot intervals using a 2-inch-diameter split spoon sample advanced with a 140-pound hammer. Blow counts were recorded for each 6-inch advancement of the spoon using Standard Penetration Test methods. Soil samples were visually classified and logged by GZA's on-site

geologist. Augers, split spoons and associated drilling equipment were steam-cleaned between borings. Boring logs are attached as Appendix F. Appendix F also contains logs of borings installed during previous studies at the site.

4.31 Soil Screening and Laboratory Analyses

Soil samples obtained from the split spoon sampler were placed in 8-ounce glass jars, allowed to equilibrate for a minimum of 10 minutes and screened for total VOCs using an H-Nu Model PI-101 photoionization detector (PID) with a 10.2-electron-volt lamp. The PID measures relative levels of VOCs in the headspace of sealed sample jars referenced to a benzene-in-air standard. Field H-Nu screening results are provided on the boring logs in Appendix F. A portion of each soil sample was retained in a clean glass jar, stored in an ice-packed cooler and transported to GZA's Newton Environmental Chemistry Laboratory (ECL) for laboratory PID screening. Laboratory PID screening procedures are attached in Appendix G; results are discussed in Section 6.00.

In addition to H-Nu screening, the water table soil samples from borings GZ-7 through GZ-11 were analyzed for VOCs by USEPA Method 8240 at GZA's ECL. Method 8240 laboratory procedures and results are attached in Appendix H; results are discussed in Section 6.00.

4.32 Monitoring Well Installations

Monitoring wells were installed by GZA Drilling, Inc. in borings GZ-7 through GZ-12. Each well consisted of 10 feet of 2-inch-diameter PVC wellscreen attached to threaded, flush-joint PVC riser pipe. No cement or glue was used in the construction of wells. The wellscreen was set in fill and natural sand to span the water table in monitoring wells GZ-7 through GZ-10 to permit the detection of floating petroleum product, if present, on the water table. Wellscreens in monitoring wells GZ-11 and GZ-12 were set in the silty sand horizon at the bottom of the borings to permit the detection of contaminants migrating at the base of the unconsolidated deposits.

Clean silica sand was placed in the annular space surrounding the wellscreen while the augers or casing were being retracted. The silica sand extends approximately 1 foot above the top of the wellscreen; the remainder of the annular space was filled with alternating layers of bentonite pellets and filter sand to the surface. Upon completion, each well was fitted with a cast-iron curb box set flush with the ground surface and grouted with cement to minimize infiltration of surface runoff. Installation details for each well are presented on the boring logs in Appendix F.

4.40 GROUNDWATER ELEVATION MONITORING

On January 15, 1990, GZA conducted a leveling survey of the six newly installed wells. Elevations were established with a Lietz Model B-1 level relative to an assumed on-site benchmark datum of 100 feet (see Figure 2 for benchmark location). Two previously existing wells were resurveyed at this time for purposes of comparison with 1988 survey data.

At the time of surveying, groundwater depths were measured in the six new monitoring wells and in the two control wells using an electronic water level reader. Relative groundwater elevations were calculated by subtracting groundwater depths from surveyed measuring point elevations. Groundwater depth measurements were obtained on January 8, 1990 and on March 26, 1990 in all of the existing wells for the purpose of identifying any changes in groundwater flow contours since GZA's 1988 survey. Measuring point elevations, groundwater depths and groundwater elevations are summarized on Table 1 and discussed in Section 5.30.

4.50 WELL HYDRAULIC CONDUCTIVITY TESTING

To obtain estimates of the hydraulic conductivity (permeability) of the saturated materials underlying the subject site, GZA conducted rising head permeability tests in monitoring wells GZ-7, GZ-9, GZ-11 and GZ-12. The tests were conducted on January 8 through 10, 1990 in accordance with GZA's standard operating procedures. Permeability values were calculated for each of these tests using methods outlined by Hvorslev.⁵ The purpose of the hydraulic conductivity testing was to obtain information concerning aquifer properties to be used in the subsequent evaluation of the migration of contaminants in site groundwater.

Prior to testing, a static water level reading was obtained with an electronic water level reader in each of the four wells. Each well was then purged until a constant water level was obtained or until there was a significant head differential from the static water level. Water levels were then measured at specified time intervals as the water level returned to its static position.

For the rising head tests, permeability is a function of the water level recovery rate after water has been removed, the intake (filter pack) diameter of the well, the intake length, the standpipe diameter, and the anisotropy of the subsurface materials. Recent permeability values, and values from previous studies conducted at the site, are summarized in Table 2.

⁵Hvorslev, M.J., "Time lag and Soil Permeability in Groundwater Observations," U.S. Army Corps of Engineers Waterways Experiment Station, Bulletin No. 36 (April 1951).

In addition, five soil samples obtained from borings GZ-7 through GZ-11 were submitted to GZA's soils laboratory for gradation analyses. Soil samples included GZ-7/S-4 (15 to 17 feet); GZ-8/S-2 (5 to 7 feet); GZ-9/S-1 (0.8 to 2.8 feet); GZ-10/S-3 (10 to 12 feet); and GZ-11/S-3 (10 to 12 feet). With the exception of sample GZ-9/S-1, all soil samples were obtained from the natural sand horizon at or below the water table. Soil sample GZ-9/S-1 was fill material obtained from above the water table. Estimates of permeability were then obtained using the Kozeny-Carmen method, an empirical method of estimating the hydraulic conductivity of a granular soil based on gradation analyses and field density measurements (Standard Penetration Test). Recent laboratory permeability values and values obtained from previous studies are also included in Table 3 and discussed in Section 5.00.

4.60 GROUNDWATER AND SURFACE WATER SAMPLING AND LABORATORY ANALYSES

As part of the Phase II study, all of the six newly installed wells, accessible previously installed wells and two surface water points were sampled. A total of 32 groundwater and surface water samples was obtained from the site. One of the groundwater samples was submitted to GZA's ECL for chemical analysis and the 31 remaining water samples were submitted to outside contract laboratories. The overall goal of the sampling and analytical program was to better characterize the nature of groundwater contamination and to evaluate the vertical and areal distribution of contaminants.

Prior to sampling, at least six times the volume of standing water in each well was evacuated to allow for the collection of a representative groundwater sample. Approximately 20 times the standing volume of water was removed from monitoring wells GZ-7, GZ-9, GZ-11 and GZ-12 as part of the hydraulic conductivity testing discussed in Section 4.50; monitoring wells GZ-11 and GZ-12 were also purged to remove the approximately 70 gallons of municipal water added to each during drilling operations. Water samples were collected with separate (i.e., one per well) laboratory-cleaned 5-foot stainless steel bailers with Teflon ball check valves.

Groundwater samples were obtained on January 9 and 10, 1990 from the six newly installed monitoring wells (GZ-7 through GZ-12) and from 11 of the 15 existing monitoring wells (GZ-1 through GZ-6 and B-1, B-2A, B-3A, B-4 and B-5) for VOC analyses. Monitoring wells MW-1 and MW-2 were not accessible at the time of our January 1990 sampling round. Monitoring wells B-2 and B-3 were not located and presumed to have been destroyed. GZA obtained groundwater samples from monitoring wells MW-1 and MW-2 on March 15, 1990. Groundwater samples were obtained in triplicate from each monitoring well for VOC analyses by USEPA Method 524.2 at Water Control Laboratories of Hopkinton, Massachusetts; duplicates were collected from monitoring wells GZ-1 and GZ-3 for QA/QC purposes.

In addition to VOC analyses, groundwater samples were collected on January 12 and March 15, 1990 from monitoring wells GZ-1, GZ-3, GZ-4, GZ-5, GZ-11, GZ-12, B-3A and MW-1 for petroleum hydrocarbon analyses. A duplicate sample was collected from monitoring well GZ-3 for QA/QC purposes. Groundwater samples GZ-1, GZ-3, GZ-3 Duplicate, GZ-4, GZ-5, GZ-11, GZ-12 and B-3A were analyzed for Total Petroleum Hydrocarbon compounds using EPA Method 418.1 (TPH-IR) at ERCO Laboratory in Cambridge, Massachusetts. Groundwater samples GZ-5 and B-3A were also analyzed for individual petroleum hydrocarbon compounds (PHC-Fingerprinting) at ERCO Laboratory. Sample MW-1 was analyzed by PHC-Fingerprinting methods at GZA's Newton ECL.

Groundwater samples were collected on March 26, 1990 from monitoring wells MW-1 and GZ-1 for base/neutral extractable analyses or petroleum aromatic hydrocarbon (PAH) analyses. The samples were collected in 1-liter amber jars and analyzed by Water Control Laboratories.

In addition to groundwater samples, surface water samples were collected in triplicate from the Aberjona River at an upstream and a downstream location, shown on Figures 2 and 4, as SW-1 and SW-2, respectively. Surface water samples, obtained by immersing VOA vials directly into the river, were collected for USEPA Method 524.2 VOC analyses at Water Control Laboratories. A duplicate sample was collected from the SW-2 location for QA/QC purposes.

Procedures were also undertaken to gauge selected monitoring wells to determine the presence of free-phase petroleum product. Monitoring wells GZ-3, MW-1 and MW-2 were gauged with separate, clear Teflon ball check valve bailers. Monitoring wells GZ-3 and MW-1 were selected for gauging because of the identification of free-phase petroleum product in these wells during previous sampling rounds; monitoring well MW-2 was selected because of its proximity and connection (via the gravel backfill installed by HET) to monitoring well MW-1. GZA detected approximately 0.4 feet of free-phase petroleum product in monitoring well MW-1 on March 15, 1990. No free-phase petroleum product was observed by GZA in monitoring wells GZ-3 (January 8, 1990) or MW-2 (March 15, 1990), or in any of the other existing monitoring wells (January 1990).

GZA prepared triplicate trip, field and bailer blanks for USEPA Method 524.2 VOC analyses at Water Control Laboratories. The trip blank was prepared by filling 40-ml vials with distilled water in the laboratory and carrying these with samples in the cooler to assess the possibility of sample contamination from transporting procedures. A field blank was prepared by filling a 40-ml vial with distilled water in the field to assess whether ambient airborne contamination in the vicinity of monitoring wells had affected sample integrity. A bailer blank was prepared in the field by filling a clean bailer with distilled water which was then emptied into a 40-ml vial; bailer blanks provide a measure of possible contamination resulting from sampling procedures.

Laboratory results for groundwater and surface water sample analyses are attached in Appendices I and J are discussed in Section 6.00.

4.70 SEDIMENT SAMPLING AND ANALYSIS

On September 12, 1990, two river sediment and two wetland sediment samples were collected at the locations shown on Figure 4. The river and wetland sediment samples were obtained by hand from the upper 12 inches and placed in 40-ml glass jars, 1-liter amber jars, and 8-ounce glass jars. The samples were chilled and transported under chain-of-custody procedures to GZA's laboratory for analysis.

5.00 GEOHYDROLOGIC SETTING

This section describes the regional and site-specific geologic and hydrogeologic conditions in the vicinity of 60 Olympia Avenue. Subsurface conditions at and in the vicinity of the site have been characterized using information gathered under this Phase II study as well as from previous studies conducted at the site by GZA and others (see Section 2.00 for summaries). Refer to Figure 2 for boring locations.

5.10 REGIONAL SETTING

5.11 Regional Geology

The portion of the 60 Olympia Avenue property being investigated for the current Phase II study is situated along the eastern floodplain of the Aberjona River. Surficial topography at and in the vicinity of the site is relatively flat with ground surface elevations averaging approximately 50 feet above mean sea level.

The predominant bedrock type which underlies most of the Aberjona River valley comprising the study area is a medium-grained igneous rock known as the Salem Gabbro-Diorite. This rock is flanked on either side of the valley by a relatively more weathered and fractured medium- to fine-grained igneous rock, the Dedham Granodiorite. Water with the bedrock occurs largely in fractures and joints. Where fractures and joints are numerous, open and well-connected, significant quantities of water may be obtained.

The bedrock valley is filled with glacial outwash deposits and recent alluvial sediments. Glacial till is found primarily in the uplands on either side of the Aberjona River valley. A thin discontinuous layer of highly compacted basal till (or lodgement till) directly overlying the bedrock has been observed in several of the well borings near Woburn's Wells G and H. Stratified drift deposits up to 140 feet thick have been found directly overlying the till and bedrock. These stratified sand and gravel deposits

form the most important aquifer in the study area. A peat layer ranging in thickness from 0 to 25 feet has been found to overlie the sand and gravel deposits in the immediate vicinity of the wetlands.

The unconsolidated valley fill deposits consist of interbedded sands, silts, clays and gravels. In general, these can be divided into three units. The uppermost unit is the sand, silt, clay and peat layer which underlies the entire wetland. This layer is generally between 2 and 10 feet in thickness, but has been found in places to be 30 feet thick. The peat layer is underlain by a 10- to 50-foot layer of coarse sands, which in turn is underlain by a unit consisting of coarse sands and gravels. This lower sand and gravel unit ranges between 20 and 50 feet in thickness.

5.12 Regional Surface Water Hydrology

As noted in Section 3.00, the Aberjona River lies within the Mystic River Basin which encompasses approximately 230 square miles of land and also includes the Annisquam, Danvers and Saugus Rivers and several smaller drainage systems.

According to the U.S. Geological Survey (USGS) Hydrologic Investigations Atlas of the area⁶, topographic relief in the Mystic River Basin is low with altitudes ranging from sea level to approximately 350 feet above sea level. The basin streams generally have low gradients; the combined Aberjona and Mystic River Systems loses about 80 feet in altitude in the 16 miles from Reading to the Amelia Earhart Dam in Somerville. Low relief and poor drainage result in numerous wetlands in the Mystic River Basin.

The USGS maintains a stream gaging station (No. 01102500) on the Aberjona River at Winchester, Massachusetts, 0.5 miles upstream from the head of the Mystic Lakes; the drainage area of the river at this point is 24.1 square miles. The USGS gaging station is approximately 4 miles downstream of the study site. Average discharge at the gaging station, for the period of 51 years of record, is 28.7 cubic feet per second (cfs).⁷ The maximum and minimum flows for the period of record are 1,330 cfs (January 25, 1979), and 0.25 cfs (October 10, 1950), respectively.

⁶Delaney, David F., and Frederick B. Gay, "Hydrology and Water Resources of the Coastal Drainage Basins of Northeastern Massachusetts, From Castle Neck River, Ipswich, to Mystic River, Boston", U.S. Geological Survey Hydrologic Investigation Atlas HA-589, 1980.

⁷U.S. Geological Survey, "Water Resources Data for Massachusetts and Rhode Island, Water Year 1990", Water-Data Report MA-R1-90-1.

The USGS also maintains a low-flow measurement station (No. 01102465) on the Aberjona River at Montvale Avenue in Woburn; the drainage area upstream of this station is 8.9 square miles.

5.20 SITE GEOLOGY

The geology of the 60 Olympia Avenue site is relatively consistent as evidenced by soil samples obtained during the current and previous phases of work at the site. The soil stratigraphy consists of fill material overlying a fine to coarse sand layer which overlies a thick silt-silty sand unit. A layer of organic peat was encountered in borings B-3, GZ-1 and GZ-4 within the sand layer during GZA's 1985 and 1988 subsurface exploration programs.

Casing and split spoon refusal was encountered only in boring GZ-11 at 64.6 feet and in boring GZ-12 at 65.7 feet; these refusals were presumed to be at the top of bedrock. Several inches of till were recovered in the split spoon sampler from just above refusal in borings GZ-11 and GZ-12.

Laboratory gradation (sieve) analyses were performed on selected subsurface soil samples at GZA's Newton Soils Laboratory for the purpose of further classifying subsurface soil profiles at the site. Results of these analyses are discussed below, and laboratory data sheets are attached as Appendix K.

5.21 Fill

Based on review of the available boring logs from the site, the fill layer ranges in thickness from approximately 3 feet in GZ-3 to 7 feet in borings GZ-10 through GZ-12. The fill is variable ranging from a very loose to a very dense, gray to brown, fine to coarse sand with some silt and trace amounts of gravel. Maximum fill thickness appears to occur along the west and south central portions of the site. None of the borings was terminated in the fill layer.

5.22 Natural Soils

The natural soils encountered during the Phase II subsurface investigation and during GZA's two previous subsurface exploration programs at the site were characterized by approximately 13 feet of a mixture of sand, sand and gravel, silty sand and organic silt beneath the fill layer. Borings GZ-1 through GZ-10 and B-1 through B-5 were terminated in this horizon at depths ranging from 12 to 17 feet below ground surface. A thin lens of organic peat was encountered in borings B-3, GZ-1 and GZ-4 within the natural soil horizon during GZA's 1985 and 1988 studies.

Laboratory gradation (sieve) analyses were performed on three soil samples obtained from the sand layer (borings GZ-7/S-3 (10 to 12 feet); GZ-9/S-2 (5 to

7 feet); and GZ-9/S-3 (10 to 12 feet). The 5- to 7-foot sample obtained from boring GZ-9 was classified as a silt and fine sand. The 10- to 12-foot samples obtained from borings GZ-7 and GZ-9 were classified as fine to coarse sand, little gravel with trace amounts of silt.

Borings GZ-11 and GZ-12 were terminated in the silt horizon which extends from approximately 20 to 60 feet below ground surface. Laboratory gradation analyses were performed on samples obtained from borings GZ-11/S-13 (58 to 60 feet) and GZ-12/S-11 (55 to 57 feet). Both samples were classified as silts although some fine sand was identified in the GZ-12 sample. This silt horizon is expected to serve as a low permeability, possibly leaky, confining layer for the upper sand aquifer.

Till was encountered at the base of the silt layer in deep borings GZ-11 and GZ-12; a maximum of 3 inches of till was recovered from each of the deep borings before casing and spoon refusal was encountered. The till is described as a very dense, gray to brown, fine to coarse sand with abundant quantities of silt and fine to coarse gravel.

5.23 Bedrock

Bedrock coring was not included in the present Phase II scope of work. Bedrock has been cored in the vicinity of the site as part of the studies related to the Wells G and H Superfund site. Review of data from borings conducted for the Superfund studies indicates that the bedrock consists of the Salem Gabbro-Diorite. It is described by NUS⁸ as "medium to coarse grained, bluish gray in color and composed of hornblende, quartz, and feldspar. The rock is highly fractured and altered."

5.30 SITE HYDROGEOLOGY

This section focuses on the rate and direction of groundwater movement at the 60 Olympia Avenue site with references being made to field data collected and calculations made during GZA's present and previous studies. Information concerning groundwater flow rates and directions is required for evaluation of contaminant migration in the groundwater.

⁸NUS Corporation, "Wells G & H Site Remedial Investigation Report Part I Woburn, Massachusetts", TDD No. F1-8607-07, NUS Job No. MA11RF EPA Site No. MAD 980732168, Contract No. 68-01-6699, October 17, 1986.

5.31 Groundwater Flow Direction

Based on studies conducted in connection with the Wells G and H site, the regional groundwater flow direction in the vicinity of the site is southwest toward the Aberjona River. Local groundwater flow at the site is also generally to the southwest toward the Aberjona River. Several regional groundwater recharge divides, as interpreted from the USGS topography maps (Lexington, Wilmington, Boston North and Reading Quadrangles, 1966-1979) appear to be located within 2 miles east (Farm Hill in Stoneham and Bear Hill in Reading) and west (Peach Orchard Hill in Burlington) of the site. Groundwater recharge at the site is expected to be limited by the high proportion of paved area.

To characterize the groundwater flow pattern at the site, groundwater measurements were taken with an electronic water level reader in the 19 existing site wells on January 8 and March 26, 1990. Groundwater elevations are summarized on Table 1, and a Groundwater Contour Plan is attached as Figure 5. In general, the shape of the groundwater contour plan has not changed since GZA's 1988 study.

The contour lines presented on Figure 5 represent interpolation between points of equal piezometric pressure in the unconfined aquifer. In general, groundwater flow is perpendicular to these contours, moving from areas of high to low piezometric pressure. Under homogeneous, isotropic conditions, groundwater contours are generally evenly spaced. Heterogeneities in the soil and areas of water flux to and from the aquifer system will provide deviations in the spacing and alignment of the groundwater contours and resulting groundwater flow patterns.

Groundwater elevation data presented on Figure 5 and summarized on Table 1 indicate a southwesterly flow of groundwater in the upper fill and natural sand aquifer across the site. The groundwater elevations obtained from monitoring wells GZ-11 and GZ-12 were not used in developing the Figure 5 contour plan because these wells are screened below the primary aquifer in the lower confining silt horizon. Owing to the presence of free-floating petroleum product in monitoring well MW-1 on the days of measurement, groundwater elevation data from this well was not used in developing the Figure 5 contour plan.

5.32 Horizontal and Vertical Gradients

Horizontal gradients are calculated from the groundwater contour plan (Figure 5) by dividing the head difference between two contours by the map distance between the contours. The horizontal groundwater flow gradient ranges between approximately 0.003 ft/ft in the northwest corner of the site and 0.006 ft/ft in the southwest portion of the site. The steeper (more closely spaced contours) gradients in the northwest portion of the site may be the result of the underground tanks and other utilities acting as a local sink for groundwater flow. Areas of inferred data,

shown as dashed contour lines on Figure 5, were not used in assessing horizontal gradients.

The installation of well clusters, with the screen of each well placed in a separate hydrogeologic unit, permits an assessment of the head elevation differences from a vertical perspective. The difference in head elevation, divided by the difference in elevation between the screened zones provides an estimate of maximum potential vertical gradient at that location. These values are used as an indicator of potential groundwater flow in the vertical direction.

Although not installed as well cluster pairs, monitoring wells GZ-4 and GZ-11 and monitoring wells GZ-7 and GZ-12 can be treated as pairs for purposes of vertical gradient calculations. Monitoring wells GZ-4 and GZ-7 represent the shallow wells screened in the upper fill/natural sand horizon; monitoring wells GZ-11 and GZ-12 are deep wells screened in the silty sand-silt horizon.

The approximate average vertical gradient potentials calculated from the two sets of groundwater elevation measurements taken on January 8 and March 26, 1990 (Table 1), are 0.006 ft/ft for the GZ-4/GZ-11 pair and 0.0034 ft/ft for the GZ-7/GZ-12 pair. The potential vertical gradient estimates indicate that a slight downward component of groundwater flow may exist in both well cluster pairs.

5.33 Hydraulic Properties

The hydraulic properties discussed in this section include hydraulic conductivity (K), transmissivity (T) and soil porosity (n). Hydraulic conductivity is a measure of the efficiency with which water moves through a particular aquifer material and is a function of both the fluid and soil matrix through which it flows. Transmissivity measures the efficiency of an aquifer, and is equal to the product of the aquifer's hydraulic conductivity (K) and its saturated thickness (b). Porosity is a measure of the relative volume of void space in a soil matrix to the total volume (void space plus solid) of soil.

The storage coefficient (s), a measure of the volume of free water stored in a unit volume of saturated aquifer material, is another important hydraulic property of groundwater aquifers. However, since the volume of water stored in an aquifer remains constant with time during steady state conditions, this particular parameter can be ignored whenever such conditions are of primary interest.

5.33.1 Hydraulic Conductivity

In this and in previous GZA studies concerning the 60 Olympia Avenue site, several data sources were used to estimate hydraulic conductivities of subsurface soils including empirical solutions based on field variable-head or rising-head wellpoint

permeability test results (Hvorslev solution) and on soil properties determined in the laboratory (Kozeny-Carmen solution). In addition, empirical solutions have been compared with published values. The following sections describe empirical determinations of hydraulic conductivities. Hydraulic conductivity data are shown on Tables 2 and 3; field and laboratory data sheets and calculations are attached as Appendix K.

As discussed in Section 4.50, variable head hydraulic conductivity testing was conducted on monitoring wells GZ-7, GZ-9, GZ-11 and GZ-12 in the field. Field tests were performed in duplicate at each of the four monitoring wells. The following equations (from Hvorslev, 1951) were used to estimate hydraulic conductivity in each well from the variable-head testing field data:

(1)

$$K = \frac{d^2 \ln(2mL/D) \ln H_1/H_2}{8L(t_2 - t_1)}$$

and for variable-head, wellpoint filter in a uniform soil (GZ-7 and GZ-9),

(2)

$$K = \frac{d^2 \ln(4mL/D) \ln H_1/H_2}{8L(t_2 - t_1)}$$

for variable-head, wellpoint filter at an impervious boundary (GZ-11 and GZ-12), where:

K = hydraulic conductivity (cm/sec or ft/day)

d = well casing inside diameter (cm or ft)

D = well sand pack diameter (cm or ft)

L = saturated sand filter length (cm or ft)

m = transformation ratio (= 1)

t = time (sec or day)

H₁ = piezometric head at time t₁ minus static head (cm or ft)

H₂ = piezometric head at time t₂ minus static head (cm or ft)

Based on duplicate field variable-head measurements and the Hvorslev solution, average hydraulic conductivity estimates for the fill-natural sand material are

approximately 7.3×10^{-3} cm/sec (20 ft/day) in monitoring well GZ-7 and 2.8×10^{-3} cm/sec (8.4 ft/day) in monitoring well GZ-9. Average hydraulic conductivity estimates for monitoring wells GZ-11 and GZ-12 are 5.3×10^{-4} cm/sec (1.5 ft/day), and 3.2×10^{-4} cm/sec (0.9 ft/day), respectively.

Laboratory estimates of hydraulic conductivity based on sieve analyses (see Section 4.50) and the Kozeny-Carmen equation are 6×10^{-2} cm/sec (170 ft/day) for soil sample GZ-7/S-3 and 9×10^{-3} cm/sec (25 ft/day) for soil sample GZ-9/S-3. In the absence of hydrometer data, a Kozeny-Carmen hydraulic conductivity solution could not be determined for samples GZ-9/S-2, GZ-11/S-13 or GZ-12/S-11. However, assuming that the silt fractions of these samples are non-plastic, hydraulic conductivity values for these three samples would be expected to range between approximately 1×10^{-5} and 5×10^{-5} cm/sec (0.03 and 0.1 ft/day) based on the Kozeny-Carmen solution.

Published values of hydraulic conductivities provided in Fetter⁹ and Heath¹⁰ range between approximately 0.5 to 5×10^4 ft/day for the sand and gravel material typical of monitoring wells GZ-7 and GZ-9 screened intervals; and 1×10^{-3} to 10 ft/day for the silt material typical of monitoring wells GZ-11 and GZ-12 screened intervals.

In general, there is good agreement among field laboratory and published hydraulic conductivity values for subsurface materials from the 60 Olympia Avenue site. To estimate the remaining hydraulic properties at the site, an average site hydraulic conductivity value of 6.6×10^{-3} cm/sec (20 ft/day) was calculated from four of the field and laboratory values for monitoring wells GZ-7 and GZ-9 (upper sand aquifer) shown by asterisks on Tables 2 and 3. The highest (170 ft/day) and lowest (7.8 ft/day) hydraulic conductivities were eliminated to avoid skewness, and the GZ-11 and GZ-12 data were not included because of uncertainties in groundwater flow direction within the silt material. For purposes of simplifying the remaining estimates of hydraulic properties, hydraulic conductivity values will be referenced in units of ft/day.

5.33.2 Transmissivity

Utilizing the hydraulic conductivities derived above, transmissivities were calculated using the following relationship:

⁹Fetter, C.W. Jr., "Applied Hydrogeology," Charles E. Merrill Publishing Company, Columbus, Ohio (1980).

¹⁰Heath, R.C., "Basic Ground-Water Hydrology," U.S. Geological Survey Water Supply Paper 2220 (1983).

$$T = K \cdot b$$

where

T = transmissivity (ft²/day)

K = hydraulic conductivity (ft/day)

b = saturated soil thickness (ft)

A saturated soil thickness of approximately 15 feet was estimated based on known depths to the silt interface (assumed to be the bottom of the upper aquifer where the contamination occurs), and the maximum groundwater elevation measured in March 1990 (96.07 feet in monitoring well B-1 relative to arbitrary 100.00-foot on-site benchmark). Using the average hydraulic conductivity of 20 ft/day, the effective average transmissivity at the site was calculated as approximately 300 ft²/day. Using the hydraulic conductivity range of 8.3 to 25 ft/day, local transmissivities in the upper sand aquifer are anticipated to range between approximately 125 and 375 ft²/day over much of the study area.

5.33.3 Porosity

The porosity of a soil is a measure of the volume of void space within a soil, and is used in estimating groundwater pore velocities (see Section 5.34). Porosity has relatively minor variability compared to the other major parameters. Soil porosities typically ranged between 0.25 and 0.55, while estimates of hydraulic conductivities can range over one or more orders of magnitude. For the fine to coarse sands and fill found at the site, a porosity of about 0.25 appears to be reasonable based on standard grain-size information (see Appendix K).

It should be noted that the above porosity may not reflect the actual pore space available for groundwater flow. Under field conditions, a percentage of the water in pore spaces can be tightly held to the surface of soil grains by surface tension reducing the active pore space. Effective porosity is the ratio of the void space through which flow can occur to the total volume. In soils with a high fines content, surface tension effects are increased leading to a diminished effective void space. We, however, used the conservative value of 0.25 in our calculations.

5.34 Groundwater Pore Velocities

Groundwater pore velocities (or transport velocities) were calculated at selected points in the upper sand aquifer around the site using a modified form of Darcy's equation:

$$V = \frac{Ki}{n}$$

where

V = groundwater pore velocity (ft/day)

K = hydraulic conductivity (ft/day)

i = hydraulic gradient (ft/ft)

n = effective soil porosity (unit less)

The hydraulic gradient (i) in the immediate vicinity of the underground tank storage area (central portion of the site) was estimated to be 0.003 ft/ft; the gradient to the south of this area (south central portion of the site) was estimated to be 0.006 ft/ft (see Section 5.32). Using the above equation and assuming a hydraulic conductivity of 20 ft/day and a porosity of 0.25, average groundwater pore velocities in the upper aquifer were estimated to be approximately 0.2 ft/day in the vicinity of the underground storage tanks and 0.5 ft/day to the south of this area.

Given the observed geologic heterogeneities at the site and the variability of the hydraulic conductivity data, local pore velocities are anticipated to vary over several orders of magnitude.

5.35 Groundwater Flow Rate

The volume of groundwater flow from the 60 Olympia Avenue site was estimated via Darcy's equation for fluid flow through a porous medium.

$$Q = Kia$$

where:

Q = rate of flow (ft³/day)

K = hydraulic conductivity (ft/day)

i = hydraulic gradient (ft/ft)

a = cross-sectional area of aquifer (ft²)

The flow area was calculated by multiplying the length of the site, which is about 680 feet, by the average effective aquifer thickness of 15 feet (average depth to silt horizon). This yields a cross-sectional flow area of approximately 10,200 square feet. Using the hydraulic conductivity of 20 ft/day and an average hydraulic gradient of 0.005 ft/ft, a flow rate of approximately 1,000 ft³/day or 7,500 gallons per day was calculated through the upper sand aquifer at the site.

5.36 Solute Transport Estimation

The transport and fate of contaminants in groundwater (i.e., solute transport) is a complex, dynamic process involving a number of interacting physical, chemical, and biological processes. Of particular importance are the five activities listed below:

1. Advection (physical)
2. Dispersion, Diffusion, and Dilution (physical)
3. Adsorption (chemical)
4. Chemical Reactions/Transformations (chemical)
5. Biodegradation (biological)

Except for advection, these processes tend to act in a manner which reduces the mean solute velocity (i.e., the velocity of the center of mass of the contaminant plume) and/or the concentration at which contaminants move. Exceptions to this general rule include chemical and biological transformations of contaminants from one chemical form to another. While such transformations may reduce the concentrations of certain contaminants, they may also result in increases in the concentrations of others.

In general, however, the factors affecting and controlling contaminant transport and fate are still not fully understood, making accurate prediction and modeling difficult. As a result, solute transport analyses typically are designed to be relatively conservative. Most involve some simplification of the overall transport and fate process by neglecting one or more of the processes which tend to reduce, degrade, and/or slow down groundwater contamination. This results in solute transport predictions which may underestimate travel times and overestimate concentrations and loadings at the receptors.

For the 60 Olympia Avenue site, a simple mass balance approach has been elected to estimate both a "worst case" scenario and a "more likely" (yet conservative) scenario for the impacts of on-site VOCs to the downgradient municipal wells "G" and "H." In both analyses, the various attenuation mechanisms which tend to reduce mean solute velocities and/or concentrations have been ignored, and conservation of mass has been assumed.

To further simplify the analysis, we have assumed the solute concentrations currently on-site will remain at similar levels for the near-term. (In actuality, the groundwater concentrations and the total mass of VOCs on -site will slowly diminish with time.) This assumption allows us to reduce the original complex transient situation to a relatively simple, yet conservative steady state situation in which the amount of mass leaving the site during a given period of time is equal to the rate at

which the mass reaches the downgradient receptors. While this is indeed conservative, it serves as an efficient screening procedure for evaluating whether or not a significant potential risk exists, and thus, whether or not additional (more quantitative) analysis and/or remediation is warranted.

Potential Receptors: There are two primary potential receptors for groundwater leaving the 60 Olympia Avenue site: the Aberjona River, located due west of the site, and the two municipal wells, wells "G" and "H," located approximately 1,500 feet and 1,000 feet due south of the site, respectively. Under non-pumping conditions at the two municipal wells, groundwater at the site is assumed to discharge directly into the Aberjona River. Under pumping conditions, however, the off-site migration pathway is somewhat less clear. In general, there are four potential groundwater pathways to the receptors:

1. all of the groundwater continues to discharge locally into the river and none of it is recaptured by the municipal wells (via induced infiltration) as it flows downstream (unlikely);
2. all of the groundwater continues to discharge locally into the stream and some of it is recaptured by the wells (via induced infiltration) as it flows downstream (possible);
3. some of the groundwater continues to discharge locally into the stream (and may or may not be recaptured via induced infiltration) and some migrates directly toward the municipal wells (possible); and
4. the groundwater capture zone of the municipal wells encompasses the site area, and all the groundwater migrates via groundwater flow directly toward the municipal wells (possible).

Prior pump testing in the area indicates that the two municipal wells do in fact induce a significant amount of infiltration from the Aberjona River.¹¹ Beyond this, however, it is uncertain as to the influence of these wells in the immediate area of the 60 Olympia Avenue property. Accordingly, for the purpose of this analysis, we have conservatively assumed that when the wells are pumping, their influence extends to the site and groundwater flow from the site is redirected directly to the well field.

¹¹deLima, Virginia, and Julio C. Olimpio, "Hydrogeology and Simulation of Groundwater Flow at Superfund Site Wells G and H, Woburn, Massachusetts," U.S. Geological Survey Water-Resources Investigations Report 89-4059, 1989.

Conservation of Mass

Method: Based on the assumptions outlined above (e.g. no attenuation, conservation of mass, steady state, etc.), we can derive the following conservation of mass equation:

$$\text{General Form: } Q_R C_R + Q_W C_W = Q_S C_S$$

where: Q_R = River flow rate (L^3/T)
 C_R = Resulting solute concentration in river (M/L^3)
 Q_W = Municipal well flow rate (L^3/T)
 C_W = Resulting solute concentration in well water (M/L^3)
 Q_S = Groundwater flow rate from impacted area site (L^3/T)
 C_S = Average solute concentration of existing groundwater (M/L^3)

For the scenario in which at least one of the wells is pumping and all the site groundwater flow is captured by the well, this equation reduces to:

$$Q_W C_W = Q_S C_S \quad \vee \quad C_W = \frac{Q_S C_S}{Q_W} \quad \vee \quad C_W = DF_1 C_S$$

where $DF_1 = Q_S/Q_W$

In the latter form, the term Q_S/Q_W can be viewed as a dilution factor, which can be applied to the source concentration to obtain a conservative estimate of the potential concentration at the municipal well field.

For the scenario in which the two municipal wells are not pumping and all the site groundwater flow goes directly to the Aberjona River, the general equation reduces to:

$$Q_R C_R = Q_S C_S \quad \vee \quad C_R = \frac{Q_S C_S}{Q_R} \quad \vee \quad C_R = DF_2 C_S$$

Dilution Factor Calculations: Using the equations outlined above, dilution factors were calculated for three different impact scenarios: (1) a worst-case scenario in which the maximum estimated groundwater flow ratio from the impacted area of the site is completely captured by the northernmost municipal well, well H; (2) a conservative, more probable scenario in which the average estimated groundwater flow rate from the impacted area of the site is captured by municipal wells H and G together; and (3) a non-pumping scenario in which groundwater flow from the

impacted area of the site discharges directly to the Aberjona River. A brief summary of the dilution factor calculations for each of these scenarios is presented below:

Case 1: Worst-Case Scenario

$$DF_1 \text{ (worst-case)} = Q_s/Q_w = \frac{600}{100,000} = .0060$$

where:

$$\begin{aligned} Q_s &= \text{maximum estimated groundwater flow rate through} \\ &\quad \text{impacted area of the site} \\ &= 600 \text{ Ft}^3/\text{d} \\ Q_w &= \text{assumed flow rate for well H alone} \\ &= 100,000 \text{ Ft}^3/\text{d (approximately 750,000 gallons per day)} \end{aligned}$$

Case 2: More-Probable Scenario

$$DF_1 \text{ (more probable)} = \frac{Q_s}{Q_w} = \frac{350}{300,000} = 0.0012$$

where:

$$\begin{aligned} Q_s &= \text{Average estimated groundwater flow rate through} \\ &\quad \text{impacted area of the site} \\ &= 350 \text{ Ft}^2/\text{day} \\ Q_w &= \text{Assumed flow rate for Wells G and H together} \\ &= 300,000 \text{ Ft}^3/\text{day (approximately 750,000 gallons} \\ &\quad \text{per day for "H" and 1,500,000 gallons per day for "G")} \end{aligned}$$

Case 3: Non-Pumping Scenario

$$DF_2 \text{ (non-pumping)} = \frac{Q_s}{Q_R} = \frac{350}{84,000} = 0.0042$$

where:

Q_S = Average estimated groundwater flow rate through impacted area of the site

Q_R = Seven day low-flow with a two year recurrence interval (Aberjona River: USGS HA-589: Station at Montvale Avenue in Woburn)

= 84,000 Ft^3/day (approximately 0.97 Ft/sec)

Please note the assumptions listed in the preceding section.

6.00 NATURE AND DISTRIBUTION OF ENVIRONMENTAL CONTAMINANTS

This section summarizes the nature and extent of environmental contamination in the site study area; Table 4 summarizes the chemical analyses performed on soil, groundwater and surface water samples obtained from the site. Organic contaminants, consisting primarily of volatile organic compounds, have been identified in soil, groundwater and surface water at the site. Contaminant distribution depends on factors such as the physical and chemical properties of contaminants, source location, site characteristics (such as geology, hydrology and topography), and weather conditions. Contaminant types and properties are discussed below, followed by a summary of contaminant distribution within each environmental medium and an assessment of potential contaminant migration.

6.10 CONTAMINANT PROPERTIES AND TYPES

Since compounds which are structurally similar will tend to have similar properties, environmental contaminants are grouped into classes. The chemical classes of contaminants observed in the site study area include VOCs, PHCs and base/neutral extractable compounds. General definitions of physical properties are discussed below followed by a description of the characteristics of each chemical class.

6.11 Physical Properties

Physical properties of chemical compounds are important factors in evaluating their environmental distribution and movement. The properties (as defined below) of a given chemical represent behavior of a pure compound under laboratory conditions. These data are used in conjunction with information on environmental conditions in evaluating the fate of environmental contaminants. Selected physical properties are defined below:

- Water Solubility: Solubility is the maximum amount of a compound that will dissolve in water at a specified temperature and pressure. Water solubility is generally useful in evaluating a contaminant's mobility and distribution in the environment. Chemicals with moderate to high solubility (greater than 100 ppm) can leach rapidly from soils into groundwater, and once there, are generally mobile. Compounds which are highly water soluble will be less likely to volatilize from water and may be more readily biodegraded by microorganisms.
- Vapor Pressure: The vapor pressure of a liquid or solid is a relative measure of its volatility in its pure state. This value expresses the pressure of the gas phase of a compound in equilibrium with the liquid or solid phase of the compound at a given temperature. Vapor pressure is important in evaluating migration of chemicals to air from other environmental media, but factors such as temperature, wind speed, water solubility, and degree of adsorption play key roles. Chemicals with vapor pressures greater than 10 millimeters of mercury (mm Hg) are considered to be highly volatile.
- Henry's Law Constant: Henry's Law Constant expresses the equilibrium partitioning of a compound between the aqueous (water) and vapor (air) phases. It is usually expressed as a ratio of the compound's equilibrium concentration in air to its equilibrium concentration in aqueous solution. When expressed in this way, high Henry's Law Constants indicate a compound's affinity for the vapor phase, and low Henry's Law Constants indicate a tendency to remain in water. In general, compounds with values below 10^{-5} atm-m³/mol are not considered highly volatile and have a greater potential for movement into groundwater.
- Organic Carbon Partition Coefficient (K_{oc}): This value is a measure of the relative sorption potential of organic compounds. K_{oc} reflects the tendency of an organic compound to be adsorbed onto the organic fraction of other soils and sediments and is generally independent of other soil properties. This value is expressed as the ratio of the amount of a compound adsorbed per unit weight of organic carbon, to the concentration of the compound in solution at equilibrium. Compounds with a high K_{oc} (greater than 1,000 ml/g) may exhibit a high sorption potential in soils and are less likely to leach into groundwater. K_{oc} values less than 100 ml/g may suggest that the compound has a higher potential to leach into groundwater.
- Octanol/Water Partition Coefficient (K_{ow}) is a measure of the tendency of a compound to partition between an organic phase (octanol) and an aqueous phase (water). K_{ow} is related to water solubility and soil

adsorption. Chemicals with Kow values (<10) have higher water solubilities and low adsorption coefficients and would, therefore, be expected to have a higher potential to leach into groundwater.

6.12 Contaminant Types

6.12.1 Volatile Organic Compounds

VOCs are termed "volatile" due to their tendency to vaporize at environmental temperatures and pressures. The VOCs observed in the study area include members of three subclasses: aromatic compounds, halogenated aliphatic hydrocarbons and PHCs.

Detected aromatic compounds include benzene, ethylbenzene, toluene and xylenes. These constituents are common components of petroleum products (gasoline, diesel fuel, etc.), paints, paint thinners, and adhesives, and are widely used in solvents. These aromatic hydrocarbons are less dense than water and have moderate solubility values with the exception of benzene, which has a high solubility value relative to the other three aromatic compounds. Volatilization may play a significant role in transport of these chemicals because Henry's Law Constants range around 10^{-3} atm-m³/mol. Aromatic hydrocarbons display a moderate degree of adsorption to particular surfaces ($K_{oc} = 100$ -1,000); benzene has the lowest K_{oc} (83) and ethylbenzene the highest (1,000). Therefore, most compounds in this subclass have the potential to leach from soils and to migrate via surface water or groundwater.

The halogenated aliphatic hydrocarbons detected at the site include methylene chloride (MeCl), trichloroethene (TCE), PCE, and 1,1-dichloroethene (DCE). MeCl and TCE are widely used as degreasing and cleaning agents. The compound 1,1-DCE is often associated with TCE as a degradation product; MeCl is a key component in paint strippers and is a component of many solvents.

Aqueous solubility values for halogenated aliphatic hydrocarbons are moderate (less than 1,000 mg/l). K_{oc} values for the compounds range from 30 to 350 ml/g, and vapor pressures are generally greater than 10 mm Hg. Adsorption to particulate matter is moderate, at best. Therefore, this subclass has the potential for migration in water. With Henry's Law Constants ranging from 10^{-2} to 10^{-3} , volatilization is also an important transport process for surficial contaminants.

Halogenated aliphatic hydrocarbons are typically more dense than water and have the potential for "sinking" in the water column as saturation is approached. The resulting DNAPL (Dense Non-Aqueous Phase Liquid) would migrate by gravity to the nearest confining (e.g., low permeability) layer.

Petroleum Hydrocarbons PHCs are typical components of gasoline, fuel oil, lubricating oil, motor oil, and a variety of other products. PHCs tend to be less dense than water and relatively insoluble, and thus can form a separate phase above the water table when present in sufficient concentrations. Lower-molecular-weight PHCs (e.g., propane) tend to be readily volatilized, while heavier PHCs (e.g., decane) absorb more strongly to soils.

6.20 CONTAMINANT DISTRIBUTION

The observed distribution of contaminants in soil, groundwater and surface water at the 60 Olympia Avenue site is discussed in the following sections. The characterizations and findings presented in this section are based on the results of analyses of samples collected as part of this Phase II study, on results from previous studies, and on GZA's current understanding of the hydrogeologic conditions at the site. Analytical results from the samples collected at the site are included in Appendices H, I and J.

6.21 Soil Gas

A total of 29 shallow soil gas samples were collected at the subject site. Each of the samples was analyzed in the field for selected volatile organic compounds: BTEX compounds (benzene, toluene, ethylbenzene and xylenes), and halogenated aliphatic compounds, specifically chlorinated hydrocarbon compounds. Soil gas survey locations are shown on Figure 3; results are presented in Appendix E and are discussed below.

The soil gas sample analyses conducted in the field were performed on a Photovac Model 10S10 gas chromatograph equipped with a heated oven and heated CPSIL-5 capillary column. Ambient air was pumped through the sampling device for at least 1 minute after each sample to minimize potential for cross-contamination. A description of the analysis method used is presented with the soil gas sampling locations and analytical results in Appendix E.

BTEX compounds were identified above the field instrument detection limit in only nine of the 29 soil gas probes. These nine sampling points were located in the vicinity of the underground waste oil tank and underground petroleum storage tanks. Total BTEX compound concentrations at these nine sampling points ranged from trace (SG-1 and SG-3) to 4.18 ppm (SG-8).

Tetrachloroethene and trichloroethene were the two chlorinated VOCs identified at the site by soil gas analyses. One or both of these compounds was detected at all soil gas locations except for SG-12, SG-13, SG-20, SG-21, SG-23 and SG-26. Where detected, chlorinated VOC concentrations ranged from trace (SG-25) to 18 ppm (SG-17).

Soil gas survey results at the site indicated that total VOC concentrations, BTEX compounds plus chlorinated VOCs, ranged from none detected to 18 ppm. Results further identified two localized areas of BTEX contamination, apparently related to the present and former underground petroleum product storage tanks at the site, and a more widespread distribution of chlorinated VOCs from an unknown source(s). No well-defined plume of either type of VOC was identified during GZA's 1989 soil gas survey.

6.22 Subsurface Soils

As described in Section 5.20, the subsurface soils encountered during the Phase II investigation consisted of approximately 7 feet of unsaturated and saturated bouldery fill over approximately 10 feet of natural sand. Approximately 40 feet of silty sand overlying glacial till was encountered beneath the sand layer in borings GZ-11 and GZ-12. The distribution of VOCs in the subsurface soils is discussed below.

6.22.1 Results of Field Screening of Subsurface Soil Samples

Individual soil samples from each test boring, GZ-7 through GZ-12, were screened in the field for the presence of VOCs using an H-Nu Model PI-101 PID equipped with a 10.2-electron-volt probe. Field screening results are presented on the boring logs in Appendix F. PID readings obtained during the field activities ranged from 0.1 to 1.2 ppm. Background PID readings ranged from 0.2 to 0.6 ppm in the field.

6.22.2 Results of Laboratory Screening and Analyses of Subsurface Soil Samples

Individual soil samples from borings GZ-7 through GZ-12 were also screened for VOCs at GZA's ECL using the H-Nu PID. Laboratory screening results, which are summarized on Table 5, ranged from none detected to 1.8 ppm. In addition, the water table soil samples from borings GZ-7 through GZ-11 were submitted for VOC analysis by USEPA Method 8240 at GZA's ECL. Results of Method 8240 analyses on the five soil samples (Table 6; Appendix H) identified trichloroethylene at 8.4 parts per billion (ppb) and tetrachloroethylene at 10 ppb in soil sample GZ-7/S-4 (15 to 17 feet); and identified total 1,2-dichloroethenes (13 ppb) and benzene (13 ppb) in soil sample GZ-11/S-3 (10 to 12 feet). No VOCs were detected in soil sample GZ-8/S-2 (5 to 7 feet), GZ-9/S-1 (0.8 to 2.8 feet) or GZ-10/S-3 (10 to 12 feet).

Previous studies conducted at the site by GZA in 1985 and 1988 identified levels of VOCs in the form of gasoline constituents in soils from borings B-2, GZ-1 and GZ-3, based on GC screening.

6.23 Water Samples

6.23.1 Volatile and Semi-Volatile Organic Compounds

All groundwater, surface water and blank samples were analyzed for VOCs by USEPA Method 524.2 at Water Control Laboratories in Hopkinton, Massachusetts. Duplicate VOC analyses were performed on samples GZ-1, GZ-3 and SW-2 (for QA/QC purposes). Table 7 summarizes these data and laboratory data sheets are attached as Appendices I and J.

VOCs were identified in all groundwater samples, and in both surface water samples; concentrations of individual compounds ranged from trace to 5,620 ppb. VOCs were detected in the bailer blank. Toluene and xylene concentrations (toluene, 0.8 ppb and xylenes, 0.6 ppb) in the groundwater sample from monitoring well GZ-12, which was sampled with the same bailer used in collecting the bailer blank, were 1.6 ppb and 2.5 ppb, respectively; some or all of the toluene and xylenes reported in the sample from GZ-12 may be the result of sampling contamination. No BTEX compounds were detected in the sample from the other deep well, GZ-11. No VOCs were detected in the trip or field blanks. BTEX compounds are typically indicative of the presence of gasoline. Chlorinated compounds are not constituents of virgin petroleum products. Groundwater from monitoring wells MW-1 and MW-2 contained the highest total levels of both BTEX and chlorinated VOCs.

Previous studies (GZA, 1985 and 1988) identified low to elevated levels of BTEX VOCs in groundwater samples B-2 (which had been located adjacent to B-2A), GZ-1, GZ-2, GZ-3, MW-1, B-2A, B-3, B-4 and B-5; low levels of chlorinated compounds were identified in groundwater samples B-3, B-5 and B-3A. Previous studies did not identify BTEX or chlorinated compounds in groundwater samples from monitoring wells B-1, GZ-4, GZ-5 or GZ-6, MW-2 or in surface water samples SW-1 or SW-2 as were identified in this study. GZA's 1985 and 1988 laboratory detection limits for BTEX and chlorinated VOCs ranged between 5 and 30 ppb, while the detection limit for these compounds analyzed by Method 524.2 in 1990 was 0.5 ppb, or approximately 10 to 60 times lower than 1985 and 1988 detection limits.

GZA's 1989 soil gas survey results correlated reasonably well with groundwater and/or soil analyses for chlorinated VOC concentrations in the areas of monitoring wells B-3A, GZ-4, GZ-7, GZ-11, GZ-12, MW-1 and MW-2 during GZA's 1990 field exploration and sampling programs. However, low to moderate levels of chlorinated VOCs were detected by soil gas methods in the vicinity of monitoring well B-2A, while groundwater from this well contained the highest levels of total chlorinated VOC concentrations, after monitoring wells MW-1 and MW-2, during the 1990 sampling round. The highest soil gas readings for chlorinated VOCs were obtained at stations SG-17 (18 ppm) and SG-19 (3.1 ppm); however, GZA did not

conduct subsurface explorations in the immediate vicinity of these soil gas stations. During GZA's 1988 study, monitoring well B-3A yielded the only groundwater sample in which chlorinated VOCs were detected (tetrachloroethene or PCE at 0.50 ppb). GZA's 1988 laboratory detection limit for chlorinated VOCs was 10 ppb, or 20 times higher than the 0.5 ppb detection limit for similar compounds by USEPA Method 524.2 in 1990.

GZA's 1989 soil gas survey results correlated reasonably well with the 1990 groundwater analyses for BTEX compound concentrations in the areas of monitoring wells MW-1, MW-2, GZ-2 and GZ-3 which are all located in the vicinity of underground petroleum storage tanks. Analytical results obtained on groundwater samples during GZA's previous studies identified BTEX compounds in MW-1 (44,600 ppb), GZ-2 (trace), GZ-3 (1,300 ppb), and B-3 (trace); BTEX compounds were also identified at 3.6 ppm in a soil sample from boring GZ-3 in 1988. Monitoring well B-3, which was not located during GZA's 1990 sampling round and was presumed destroyed, had previously been located in the vicinity of monitoring wells GZ-2 and GZ-3, approximately 25 feet west and downgradient of the underground petroleum fuel storage tanks (see Figure 2).

GZA's 1989 soil gas results did not identify BTEX compounds in the vicinity of monitoring wells GZ-1 or B-2A, yet groundwater samples from these two wells yielded the highest total BTEX compound concentrations at the site, after groundwater from monitoring well MW-1 during the 1990 sampling round. GZA's 1988 analytical results identified BTEX compounds in soil (4,100 ppb) and groundwater (390 ppb) from monitoring well GZ-1 and in groundwater from monitoring well B-2A (320 ppb). In addition, 1,600 ppb of aromatic compounds detected in a groundwater sample obtained from monitoring well B-2 during GZA's 1985 original site assessment and were indicative of gasoline. Boring B-2, which was not located during GZA's 1988 or 1990 studies and was presumed to have been destroyed, had been located approximately 2 feet to the north of and adjacent to the existing monitoring well B-2A.

Seven groundwater samples (GZ-1, GZ-3, GZ-4, GZ-5, GZ-11, GZ-12 and B-3A) were analyzed for total petroleum hydrocarbon concentrations (TPH-IR) by USEPA Method 418.1 at ERCO Laboratory in Cambridge, Massachusetts. A duplicate TPH-IR analysis was performed on groundwater sample GZ-3 for QA/QC purposes. Groundwater samples GZ-5 and B-3A were also analyzed at ERCO Laboratory for PHC-Fingerprinting by a modified ASTM Method D3328. A groundwater sample from MW-1 was analyzed at GZA's ECL for petroleum hydrocarbon compounds (PHC-Fingerprinting) by a modified ASTM Method D3328. The TPH-IR method is capable of quantifying total petroleum hydrocarbon concentrations, while the PHC-Fingerprinting method is capable of quantifying total PHC concentrations and identifying individual petroleum hydrocarbon compounds.

Laboratory data sheets for PHC analyses are attached as Appendices I and J, and these data are summarized on Table 8.

TPH-IR analyses identified concentrations in groundwater sample GZ-5 at a concentration of 2.0 ppm. TPH-IR analysis did not identify total petroleum hydrocarbon concentrations above laboratory detection limits in samples GZ-1, GZ-3, GZ-4, GZ-11, GZ-12 or B-3A. Petroleum hydrocarbon fingerprinting analysis detected total petroleum hydrocarbons in sample MW-1 at a concentration of 1,900 ppm, in sample GZ-5 at a concentration of 0.26 ppm, and in sample B-3A at a concentration of 0.04 ppm. The PHC-Fingerprinting analytical method did not identify individual PHCs above laboratory detection limits in groundwater samples GZ-5 or B-3A, but did identify No. 2 fuel oil in the MW-1 groundwater sample.

Groundwater samples from monitoring wells GZ-4 and MW-1 were analyzed for petroleum hydrocarbon compound (PHC-Fingerprint methods) as part of GZA's 1988 study. Petroleum hydrocarbon concentrations were below laboratory detection limits for sample GZ-4; a concentration of 3,600 ppm of No. 2 fuel oil was identified in sample MW-1.

Groundwater samples were obtained from monitoring wells MW-1 and GZ-1 were analyzed for base/neutral extractable compounds or PAH compounds by Water Control Laboratories using USEPA Method 8270. Of the 16 compounds which can be identified by Method 8270, only naphthalene was identified, at a concentration of 240 ppb, in the MW-1 groundwater sample. Naphthalene was also detected in this groundwater sample at a concentration of 4,370 ppb by 524 VOC analysis. Laboratory data sheets for the PAH analyses are attached as Appendix I.

The areal distribution of BTEX and chlorinated compounds identified in water samples during the present Phase II study is presented in Figures 6 and 7, respectively. In comparing the areal distribution of BTEX and chlorinated compounds observed during previous studies with that observed during the present study, it appears that subsurface contamination is migrating in an inconsistent pattern about the site. GZA further anticipates that multiple on-site sources may be contributing to the observed on-site BTEX contamination distribution and that an off-site source(s) for chlorinated VOCs is highly probable.

6.23.2 pH and Specific Conductance

In addition, groundwater samples from monitoring wells GZ-11 and GZ-12 were collected in 5-gallon intervals during purging and development of these wells on January 9 and 10, 1990. Groundwater samples from monitoring well GZ-11 were screened in the field for pH and specific conductance. Because of a faulty meter calibration mechanism, only a select five groundwater samples from GZ-12 were screened for pH and specific conductance in GZA's Newton ECL. The pH is a

measure of the acidic or basic nature of the water sample, and specific conductance is a measure of dissolved constituents in the sample. Measurements were obtained with an Extech Model pH/conductivity meter.

Approximately 70 gallons of municipal water were added to borings GZ-11 and GZ-12 during drilling operations; approximately 120 gallons were removed from each well during well development. Monitoring well GZ-11 was pumped until the pH and conductivity stabilized from respective values of 7.60 to 6.36 and 340 $\mu\text{S}/\text{cm}$ to 980 $\mu\text{S}/\text{cm}$; municipal water obtained from a tap at the site yielded a pH reading of 7.68 and a specific conductance reading of 1,300 $\mu\text{S}/\text{cm}$.

Readings stabilized on GZ-11 groundwater samples after approximately 60 gallons of water had been purged. GZA anticipates that monitoring well GZ-12 stabilized after approximately the same purge interval. Stabilized pH and conductivity values for these samples were as follows:

	pH	Specific Conductance ($\mu\text{S}/\text{cm}$)	Temperature ($^{\circ}\text{C}$)
GZ-11	6.36	980	5.4
GZ-12	6.38	783	5.1

These pH and conductivity values reflect the 100-gallon purge samples and are typical for groundwater in developed areas of New England.

7.00 RISK CHARACTERIZATION

7.10 INTRODUCTION

7.11 Regulatory Framework

As part of the Phase II Assessment, GZA completed a public health and ecological risk characterization for the 60 Olympia Avenue (Olympia Nominee Trust) site in Woburn, Massachusetts.

The MCP requires that a public health and environmental risk characterization be completed as part of a Phase II Study. The risk characterization was completed in accordance with the requirements for Phase II assessments under the MCP, as outlined in 310 CMR 40.545(g) and (h), and DEP guidance for meeting these requirements (DEP, May 17, 1989). This guidance is presently limited to public health risk

characterization. Therefore, USEPA Federal and Region 1 guidance documents for ecological risk characterization were consulted (USEPA, February, 1989b; USEPA, March, 1989a; USEPA, February, 1991).

As part of our Phase II study, DEP, Northeast Region, requested in a letter dated May 9, 1989 that a Phase II Risk Characterization Scope of Work be submitted prior to the commencement of the risk characterization work. The scope of work dated May 1990, was based upon the draft DEP document "Suggested Outline, Content and Format of Phase II Human Health Risk Assessment Scope of Work." The comments contained in the August 6, 1990 DEP letter, prepared by Ms. Rodene A. DeRice and Mr. Richard J. Chalpin, were addressed in a response letter submitted to DEP by GZA on September 30, 1990. The scope of work was subsequently amended to reflect these changes. The scope of work and related DEP correspondence are attached in Appendix B.

To comply with these requirements, a public health and environmental risk characterization was completed to evaluate the level of human health and ecological risk associated with exposures to oil and hazardous material (OHM) under current and reasonably foreseeable future uses of the 60 Olympia Avenue site. Workers may be exposed in the future to constituents associated with oil and gasoline and chlorinated VOCs at the site assuming continued industrial use of the site. The constituents which have migrated or may migrate from the site to the Aberjona River and the area potentially supplying Wells G and H were also evaluated.

As stated in the DEP letter of May 9, 1989, prepared by Ms. Rodene A. DeRice and Mr. Richard J. Chalpin, as well as subsequent telephone conversations, DEP considers that a foreseeable future use of groundwater migrating from the site is as a source of drinking water, as DEP believes it is within the area of influence of Woburn's Municipal Wells G and H. As described in Section 2.33, these two wells were closed in 1979, following identification of petroleum and chlorinated solvents in the groundwater attributed to a regional contamination problem, and have remained closed since that time.

Conversations with Mr. William Neiman of the City of Woburn Department of Public Works indicate that the groundwater in the vicinity of the site is not currently used for any purpose. All homes, commercial, and industrial facilities are connected to either the Ray Roc Supply (Horn Pond Valley) or to the public (MWRA) supply with a remote reservoir source.

Previous studies related to the Wells G and H site, as well as the reports prepared by GZA (GZA, 1985; GZA, 1988; and GZA's 1989 soil gas survey, attached to this report as Appendix E), indicate that chlorinated VOC contamination appears to be a regional problem. However, as per DEP's request (August 6, 1990), this risk characterization will focus on both the petroleum contaminants potentially associated

with the 60 Olympia Avenue property and the chlorinated VOCs present in groundwater migrating beneath the site (Table 9).

7.12 Site Background

As previously noted, approximately 7 acres of the 60 Olympia Avenue site are paved and currently being used as a truck terminal. It is likely that future use of the site will remain as industrial. Remaining portions of this 21-acre site are primarily vegetated wetlands along the Aberjona River. The area north of the site across Olympia Avenue is occupied by both light manufacturing and commercial facilities. Although the 60 Olympia Avenue property includes land to the west of the Aberjona River, the property covered by the present study is bounded to the west by the Aberjona River and associated wetlands. The site is bounded to the south by the wetlands, and to the east by undeveloped forest land, which is zoned as an "office park" area by the Woburn Engineering Department and Assessor's Office. Because of restriction on wetlands development under federal and state statutes, it is likely that much of this portion of the property will remain wetlands.

For the purposes of this risk characterization, the site is defined as the paved area upon which the facility is located; being east of the Aberjona River, and surrounding areas to which contaminated groundwater or stormwater runoff might reasonably be expected to migrate. The groundwater from beneath most of the site generally flows in the former tank area and adjacent to the river, flow is westerly and in the northwestern corner of the site, flow is northwesterly. The potential receptors of groundwater discharge and stormwater runoff have been identified as the Aberjona River, and the wetlands surrounding the site and the area potentially supplying Wells G and H.

7.13 Hazard Identification

The purpose of the hazard identification was to identify the nature and distribution of petroleum associated and chlorinated VOCs identified at the 60 Olympia Avenue site and to provide toxicity information on the detected compounds. The compounds to be evaluated in the public health and ecological risk characterizations are presented in Table 9.

Compounds which are associated with petroleum contamination and chlorinated VOCs associated with regional contamination, have been detected in groundwater samples, in surface water and sediment samples from the Aberjona River, in sediment from the swamp south of the site, and in soil and soil gas samples underneath the pavement (GZA, 1985; GZA, 1988; GZA, 1989; Ebasco Services, Inc., 1988; Hydell-Ester Technologies, 1987). Petroleum-associated aromatic VOCs such as benzene, toluene, ethylbenzene, xylenes (BTEX); one PAH, naphthalene; alkylated benzenes; and a variety of chlorinated VOCs have been detected in groundwater samples. The

petroleum constituents were detected primarily in groundwater samples from wells proximate to the source area. The potential source areas for the petroleum associated contaminants include the areas surrounding the abandoned gasoline fuel pump island, the currently operating diesel fuel pump, and the general area in which underground petroleum fuel storage tanks are located. The highest concentrations of the petroleum-associated compounds were detected at well MW-1. In addition, chlorinated VOCs associated with regional contamination have been detected in site groundwater. A summary of the most recent groundwater data is provided in Table 10.

Low levels of BTEX, the gasoline additive MTBE and the chlorinated VOCs 1,2-dichloroethenes, PCE, and TCE, have been detected in soil from eight boring locations. Soil sample 1, S-3 appeared to have the highest concentrations of the petroleum constituents (Table 11).

Additionally, soil gas samples were collected in 29 locations at the site. Low concentrations of BTEX compounds were detected in fewer than half of the locations. Two chlorinated VOCs (PCE and TCE) were detected at more than half of the locations sampled. A summary of this soil gas data is provided in Table 12.

Surface water data from samples collected from the Aberjona River indicate that the levels of petroleum constituents and chlorinated VOCs are essentially the same upstream of the site as downstream (Table 13).

Sediment samples from the Aberjona River were analyzed for VOCs. No VOCs were detected in the upstream sample; the downstream sample contained low concentrations of acetone and MTBE (Table 14). River sediment near 60 Olympia Avenue was analyzed for semi-volatile organic compounds (SVOCs) during the Wells G and H Hazard Assessment conducted by Ebasco Services (1988). PAHs in river sediment were higher upstream of the site than downstream (Table 15). Ebasco Services' surface water and sediment sampling locations near the site are shown on Figure 4. Re-suspension and the subsequent migration of upstream sediment may be the primary source of PAH contamination in the river adjacent to the site. Although the only PAH detected in groundwater at the site was naphthlene and it was not detected in river sediment downstream of the trucking facility, GZA has reexamined the SVOC data for site sediment in light of recent sediment effects values (Long and Morgan, 1990) (Table 15).

Wetland soil from the swamp south of the trucking facility contained low levels of the gasoline constituent toluene in a sample taken near the parking lot stormwater outfall (Table 16).

In addition to the current extent of contamination, site information related to potential future migration of groundwater to off-site receptor locations, including

groundwater flow direction toward Wells G and H, and discharge to the wetlands and the Aberjona River has been further defined. Based on review of available information, most of the contaminated groundwater from the former tank area is likely to discharge into the Aberjona River at the northwest portion of the site. Groundwater beneath the southern portion of the site appears to flow southerly towards the Aberjona River and its associated wetlands. Concentrations are likely to be significantly diluted by surface water and groundwater discharge into the river.

Toxicity profiles were compiled for each of the compounds addressed in this risk assessment (Appendix L).

7.20 PUBLIC HEALTH RISK CHARACTERIZATION

7.21 Dose-Response Assessment

7.21.1 Identification of Toxicity Values

The dose-response assessment describes the observed effects of OHM in humans and/or laboratory animals. Dose-response information was compiled for each OHM evaluated in the risk assessment. USEPA Reference Doses (RfDs) or DEP Allowable Threshold Concentrations (ATCs) were used for evaluation of potential non-carcinogenic (threshold) effects. USEPA Carcinogenic Potency Factors (CPFs) are used for evaluation of potential carcinogenic (non-threshold) effects.

The RfD represents a human intake level of a chemical, expressed in mg/kg/day, that is not likely to cause adverse effects when exposure is long term (lifetime). RfDs are developed by an USEPA inter-office work group chaired by the Office of Research and Development. The RfD is usually based on chronic animal studies. Chronic RfDs are used to evaluate chronic exposure in humans; defined as being greater than seven years or 10 percent of a lifetime in duration. RfDs have also been developed for subchronic exposures; defined as being three months to less than seven years in duration.

The ATC is a concentration of the OHM in air which would not be expected to result in adverse non-carcinogenic health effects. ATCs are derived by DEP from the Threshold Effects Exposure Limits (TELEs). Acceptable daily doses for inhalation are derived from ATCs and standard exposure assumptions, including inhalation rates and body weight.

CPFs are used for the evaluation of exposures to potential carcinogens. CPFs are derived by the USEPA's Carcinogen Assessment Group (CAG). CPFs are derived as the upper 95 percent confidence limits on the slope of the dose-response curve. These values are used to estimate potential carcinogenic risk per unit of exposure over a lifetime. CPFs are expressed in units of (mg/kg/day)⁻¹.

The USEPA has provided RfDs and CPFs for exposures through the routes of ingestion and inhalation. These toxicity values were obtained from the USEPA's Integrated Risk Information System (IRIS) (USEPA, 1990) or from the USEPA Health Effects Assessment Summary Tables, when not listed in IRIS (USEPA, July 1990). ATCs were obtained from DEP guidance when inhalation RfDs are not available from EPA (DEP, May 1990). The target organ or health effect associated with exposure and EPA's weight of evidence classification for potential carcinogenicity were also provided for each OHM. The toxicity values for ingestion and inhalation exposure to the petroleum associated constituents and chlorinated VOCs identified at the site are summarized in Table 17.

Since toxicity values were not available for the alkylated benzenes, the potential toxicity associated with exposure to these compounds has been qualitatively discussed.

7.21.2 Identification of Public Health Standards

The MCP requires that applicable or suitably analogous public health standards, guidelines, and policies be identified for compounds detected in groundwater and surface water. These criteria are not available for soils and sediment. Table 18 summarizes the applicable drinking water standards and guidelines for the petroleum associated compounds and chlorinated VOCs identified at the site. Clean-up levels are not currently available from DEP for any media.

7.22 Exposure Assessment

In the exposure assessment, the mechanisms by which chemicals may reach human receptors under current and reasonably foreseeable future uses of the site were evaluated. To complete the exposure assessment, migration pathways and potential human receptors were identified; potential exposure points and routes were determined; and exposure point concentrations were identified or estimated, as appropriate. Average daily doses were estimated based on conservative exposure assumptions and factors in accordance with state and federal guidance. We reviewed current and potential exposure pathways to site contaminants, and described them below. In addition, the potential exposure pathways and receptors are summarized in Table 19.

7.22.1 Identification of Potential Human Receptors, Exposure Points and Exposure Routes

Ebasco's "Endangerment Assessment for the Wells G & H Site

In Ebasco's human health risk assessment of the Olympia Nominee Trust property, they defined the site as a 21-acre parcel, including a strip of

undeveloped land to the west of the Aberjona River. However, as described in Section 7.12 of our risk assessment, we have defined the western boundary of the site as the Aberjona River and did not address soil contamination present in property further west. Because of this difference in the definition of the study site, three exposure pathways evaluated in Ebasco's assessment were not included in our risk characterization. Specifically, inhalation of fugitive dusts and dermal contact with soils by residents riding dirt bikes over unvegetated site portions, and dermal contact and incidental ingestion of soils on the western side of the Aberjona by facility workers were not evaluated in GZA's human health risk assessment.

On-Site Exposures

As described in Section 1.20, the study site is currently paved or covered by buildings (i.e., there is no access to soils) and therefore on-site exposures to OHM in soils are not likely to occur. In addition, groundwater is not used for either truck terminal operations or for drinking purposes.

Future exposures to OHM in on-site soils are limited to facility workers during theoretical construction activities involving excavation beneath pavement. On-site construction workers may come into direct contact with contaminated soils (dermal absorption and incidental ingestion) and may be exposed through inhalation of volatilized contaminants released from the soils as soil gas. As this industrial portion of the site is almost completely fenced and generally inaccessible to the public, the potential for exposure to trespassers during excavation activities is minimal.

Off-Site Exposures

Wells G and H

Exposures to petroleum constituents and chlorinated VOCs in groundwater which may migrate from the site to the area of Wells G and H were considered under reasonably foreseeable future conditions, as required by the DEP. Although the site groundwater is not currently being used for drinking water, DEP considers that migrating site groundwater could be used for drinking water, as the site is located within the area of influence of Woburn's Municipal Wells G and H. Potential receptors include both adult and child residents in the vicinity of the site who may be serviced by Woburn municipal wells. Exposure pathways for these receptors which were evaluated in this risk characterization include ingestion, dermal absorption and inhalation.

Aberjona River

The Aberjona River is a discharge area for the site groundwater. Exposures to this medium under future conditions were assessed in the risk characterization. The DEP's surface water classification (goal) for the Aberjona River is Class B. Based on this classification, the river is designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary recreation. The current river water quality does not support (NS) this classification; water quality problems include elevated levels of ammonia, coliform bacteria, and metals, in addition to low dissolved oxygen (DEP, April 1989).

At the time of a GZA site visit on March 15, 1990, the river was observed to have relatively low flow and to contain significant quantities of debris. Refuse which had been discarded into the Aberjona River included tires, oil containers, aluminum cans, and paper products. Additionally, a makeshift "footbridge" had been erected approximately 2 feet above the level of the river. Photograph 1 in Appendix M is a view from the makeshift "footbridge" of the trucking facility.

Based on conversations with local health department officials, current river conditions in the vicinity of the site and the industrial/commercial nature of the surroundings, it seems unlikely that residents would participate in formal recreational river activities, such as fishing. Therefore, potential negative impacts to the human food chain, i.e. due to fish consumption, are unlikely. However, through activities such as playing/pushing or swimming, incidental contact with the river may occur. Potential receptors to the Aberjona River (surface water) include both adult and child residents who may incidentally contact (dermal absorption and incidental ingestion) surface water.

7.22.2 Identification of Exposure Point Concentrations

Whenever possible, actual monitoring data were used to identify exposure point concentrations. Monitoring data from GZA's October 1988 Hydrogeological Assessment Report, and October 1989 Soil Gas Survey were used to help identify soil and soil gas exposure concentrations, respectively. The exposure point concentrations for inhalation were estimated using the average concentration of compounds detected in soil gas and a dispersion factor of 100. This dispersion factor was chosen to represent the air concentration in a trench that would result after diffusion of soil gas through the soil into the trench air space and natural ventilation of the trench with fresh ambient air.

Groundwater exposure point concentrations at Wells G and H and Aberjona River were based on current site groundwater data and mass flux and dilution calculations. Geometric mean groundwater concentrations were used as the basis for these exposure point concentration calculations. The geometric mean

concentrations were calculated based on the most recent data from all available groundwater well locations, including those outside the identified source area for the petroleum contamination. To be conservative (i.e., protective of human health), one-half the detection limit was used to represent exposure point concentrations reported as "trace" or "not detected." The samples collected from wells MW-1 and MW-2 required significant dilution prior to their analyses, resulting in high limits of detection for individual compounds. The use of geometric means is an appropriate method for estimating groundwater and surface exposure point concentrations because contamination is often log normally distributed. The use of geometric means may overestimate the risks associated with these exposure pathways. The dilution factors used to estimate exposure point concentrations at Wells G and H and in the Aberjona River were 167 and 250, respectively. These dilution factors were based on anticipated groundwater flow rates through the site; and anticipated regional groundwater discharge and Aberjona River flow rates. Please refer to Section 5.30 for additional information regarding these calculations.

7.22.3 Selection of Risk Characterization Method

The MCP describes four methods for site health risk characterization. The appropriate method is selected once potential receptors, exposure points, and exposure routes are identified, and it is known which OHMs are or are likely to be present at these exposure points.

The method described in 310 CMR 40.545 (3)(g) 3.b. (referred to as Method 3.b.) has been selected as the appropriate method for risk characterization of the 60 Olympia Avenue site. This selection was based on the potential transportation of the petroleum constituents and chlorinated VOCs at the site to exposure points through multiple media (soils, groundwater, air and surface water) and the absence of applicable or suitably analogous standards for each constituent detected in each medium.

7.22.4 Estimation of Average Daily Doses

As required by Method 3.b., Average Daily Doses (ADDs) for each OHM were estimated for each receptor at each receptor point via each applicable exposure route. ADDs represent the amount of OHM contacted and available for absorption into the body. ADDs were calculated as the amount of OHM taken into the body per unit body weight per unit time (mg/kg/day). Subchronic and Chronic ADDs were developed to evaluate exposure to non-carcinogenic compounds; lifetime ADDs were estimated to evaluate exposure to carcinogenic compounds. ADDs were estimated by multiplying exposure point concentrations and exposure factors developed in accordance with state and federal guidance (DEP, May 1989; USEPA, July 1989; USEPA, December 1989; and USEPA, Region 1, February 1989a).

Exposure factors for subchronic and chronic noncarcinogenic effects, and carcinogenic effects were calculated for direct contact to soils; inhalation of soil gas; ingestion, direct contact and inhalation exposures to groundwater; and direct contact and incidental ingestion of surface water (Aberjona River). Assumptions, equations and calculated exposure factors for exposures to soils, soil gas, groundwater and surface water are provided in Tables 20, 21, 22, and 23, respectively.

7.22.5 Exposure Profiles

Exposure profiles were developed to describe each receptor and how that receptor may be exposed under current and/or reasonably foreseeable future site conditions (see Table 19). Future on-site construction workers may be exposed through direct contact to soils and associated volatilized contaminants on facility grounds, and residents from abutting properties through incidental contact with the Aberjona River.

7.23 Risk Characterization

7.23.1 Comparison with Public Health Standards

Site and exposure point concentrations of compounds detected at the site were compared to applicable or suitable analogous standards. Average concentrations of petroleum constituents and chlorinated VOCs detected in groundwater in the most recent sampling rounds were compared to Massachusetts Groundwater Standards (310 CMR 6.07). These standards specify requirements for permitted discharges of pollutants to groundwater.

Predicted concentrations of compounds at Wells G and H were compared to both Massachusetts Drinking Water Standards and Guidelines (DEP, October 1990), and federal Primary and Secondary Drinking Water Regulations (40 CFR 141, 142, and 143). None of the compound concentrations were greater than their respective applicable standards in groundwater. The predicted exposure point concentrations and the relevant standards are indicated on Table 24.

7.23.2 Evaluation of Non-Carcinogenic and Carcinogenic Risks

Exposures to OHM were also quantitatively evaluated using the toxicity values and the ADDs described in previous sections. Non-carcinogenic and carcinogenic effects were assessed separately.

Non-Carcinogenic Effects

For each OHM, the estimated ADD was divided by the appropriate RfD to yield a Hazard Index:

$$\text{Hazard Index} = \text{ADD}/\text{RfD}$$

The Hazard Index yielded a general indication of whether exposures are likely to result in adverse health effects.

For multiple chemical exposures, single Hazard Indices were summed to yield a cumulative Hazard Index. This approach assumes an additivity of toxic effects by the same mechanism and similar effects on target organs. Consequently, the application of this approach to a mixture of compounds that are not expected to induce the same type of effects may have overestimated the potential for effects.

For each receptor a total site Hazard Index was derived by summing the cumulative Hazard Indices for each applicable exposure pathway. This calculated total site Hazard Index was compared to the total site non-cancer risk limit of 0.2 specified in the MCP.

Carcinogenic Effects

Carcinogenic risks from exposure are expressed as probabilities. To assess incremental lifetime cancer risks from exposures to individual OHM, the lifetime ADDs were multiplied by their respective CPFs to yield lifetime cancer risk estimates:

$$\text{Risk} = \text{ADD} \times \text{CPF}$$

For multiple chemical exposures, single OHM risk estimates for a specific exposure were summed to yield a cumulative risk estimate. This summation assumes that individual intakes are small. It also assumes independence of action by the OHM involved (i.e., that there are no synergistic or antagonistic chemical interactions and that all chemicals have the same toxicological mechanism and endpoint).

For each receptor, a total site risk estimate was derived by summing the cumulative risk estimates for each applicable exposure pathway. Calculated total site risk estimates were compared to the total site risk limit of 1×10^{-5} specified in the MCP. This level represents a probability of one incremental cancer case per 100,000 people exposed.

Construction Workers

Probable future risks associated with direct contact to soils by adult construction workers are presented in Table 25. The cumulative subchronic

hazard index was 6.6×10^{-5} . The cancer risk estimate for potential carcinogenic effects was 3.4×10^{-11} .

Probable future risks associated with inhalation of soil gas by adult construction workers are presented in Table 26. The cumulative hazard index was 1.3×10^{-1} , while the cancer risk estimate for potential carcinogenic effects was 8.2×10^{-7} .

Probable future risks associated with both direct contact to soils and inhalation exposure to soil gas by construction workers are summarized in Table 29. The cumulative subchronic hazard index was 1.3×10^{-1} . The total cancer risk estimate for potential carcinogenic effects was 8.2×10^{-7} .

Residents

Risks associated with ingestion, inhalation, and dermal contact exposures to groundwater by child and adult residents are presented in Table 27. The cumulative subchronic hazard index for children residents was 4.6×10^{-4} . The cancer risk estimate for potential carcinogenic effects to adult residents was 9.1×10^{-7} .

Risks associated with direct contact to and incidental ingestion of surface water (Aberjona River) by child and adult residents are presented in Table 28. The cumulative subchronic hazard index for child residents was 3.3×10^{-5} . The cancer risk estimate for potential carcinogenic effects to adult residents was 4.2×10^{-8} .

A summary of the probable future risks associated with both exposures to groundwater and surface water by child and adult residents is contained in Table 29. The cumulative subchronic hazard index for child residents was 4.9×10^{-4} . The cancer risk estimate for potential carcinogenic effects to adult residents was 9.5×10^{-7} .

7.24 Public Health Risk Assessment Summary

The MCP indicates that remedial response at a site is necessary if any exposure point concentrations exceed applicable public health or environmental standards, or if any hazard index exceeds 0.2 or total cancer risk exceeds 10^{-5} .

Assuming that the two identified potential receptor groups (adult construction workers and residents) would directly contact soil and inhale soil gas, or ingest, inhale and dermally contact groundwater, and directly contact and incidentally ingest surface water, respectively, total site hazard indexes and total site cancer risks were calculated by summing each of the pathway-specific cumulative indices and risk estimates for each receptor (Table 27).

Results indicated the site poses risks below acceptable public health risk levels regarding both non-carcinogenic and carcinogenic effects for both receptor groups. As none of the risks estimated for the two identified potential receptor groups (adult construction workers, child and adult residents) exceeded DEP acceptable risk levels, development of cleanup goals for on-site media (groundwater, surface water and soil) and subsequent remediation, is not required.

7.30 SAFETY AND PUBLIC WELFARE RISK CHARACTERIZATION

DEP has issued limited policy and guidance for this component of the risk characterization. Site conditions were compared to available safety and welfare standards and policies. No safety issues, such as physical dangers, or welfare issues, such as nuisance odors, were identified.

7.40 ECOLOGICAL RISK ASSESSMENT

In addition to potential public health risks, the ecological community surrounding the 60 Olympia Avenue facility may also be affected by contamination. Chemicals present at the site or migrating off-site may be toxic to plants and animals exposed to these substances via the air, water, soil, sediment or food chain. Ecological risks associated with exposure to the paved portion of the site will not be addressed (Photograph 1).

GZA analytical data summarized in Section 5.00 and information from the Endangerment Assessment for the Wells G and H Site (Ebasco Services, 1988) and the Wells G and H Wetlands Assessment (Alliance Technologies Corporation, 1986) were used to assess ecological risk.

The purpose of this ecological risk assessment is to identify potential ecological effects on the Aberjona River and wetlands in the vicinity of the 60 Olympia Avenue facility from exposure to site petroleum associated and chlorinated VOCs. In addition, although they presently have no on-site source, the potential ecological risk of SVOCs in the river sediment in the vicinity of the trucking facility (Ebasco Services, 1988) are reassessed due to recently published levels of sediment contamination shown to cause biological effects (Long and Morgan, 1990) (see Section 7.45).

The ecological risk assessment contains the following elements:

- . Identification of chemical compounds in environmental media which may adversely effect flora and fauna in the vicinity of the facility, particularly the adjacent Aberjona River and wetlands.
- . Characterization of the site and surrounding environment to identify floral and faunal receptors which may be exposed to the contaminated media.

- . Identification of potential exposure pathways and estimation of potential exposure point concentrations.
- . Review of the toxicological guidelines and literature for information on the contaminants of concern.
- . Comparison of exposure point concentrations of contaminants to toxicological endpoints, and discussion of potential ecological effects.

7.41 Identification of Contaminants and Contaminated Media of Concern

The contaminated media to which ecological receptors in the vicinity of the 60 Olympia Avenue site may be exposed and the contaminants most likely to affect biota in those media are discussed in Section 7.13 (Hazard Identification).

This ecological risk assessment focuses on petroleum and chlorinated volatile organic compound contamination at the site. Previous studies performed by Alliance Technologies Corporation, Inc. (1986) and Ebasco Services, Inc. (1988), identified petroleum constituents in site soil and sediments, and chlorinated VOCs in site surface water and soil. These studies indicated that the chlorinated VOCs appear to be a regional problem, due to the extremely high levels detected in some areas of the Wells G and H Superfund site.

Table 9 lists the site associated (VOCs) and regional contaminants (chlorinated VOCs) detected during this study that are evaluated in the ecological risk assessment. They include aromatic VOCs, chlorinated VOCs, one PAH, and MTBE. VOCs, chlorinated VOCs and one polynuclear aromatic hydrocarbon were detected in the groundwater; low levels of toluene were detected in wetland soil; acetone and MTBE were detected at low levels in river sediment; and low levels of chlorinated VOCs were detected in river water.

As mentioned in the previous section, PAHs detected by Ebasco Services (1988) presently have no on-site source; however, the levels in sediment adjacent to the site are elevated.

7.42 Site Characterization and Identification of Potential Environmental Receptors

The purpose of the site characterization and identification of potential environmental receptors is to identify "sensitive areas" as defined by the MCP in the vicinity of the 60 Olympia Avenue facility. "Sensitive areas" include wetlands, areas subject to flooding and sensitive terrestrial/aquatic habitats which would include habitat of threatened, rare, or endangered species or species of special concern.

Extensive characterization of the environment of the Wells G and H site has been performed by others (Alliance Technologies, 1987; Ebasco Services, 1988). Alliance Technologies sampled the Aberjona River at various locations within the Wells G and H site for plankton, benthic organisms and water quality parameters (dissolved oxygen and temperature). In addition, they characterized the major cover types and wildlife that might be present. The 1988 Ebasco Services report primarily drew on information in the 1987 Alliance Technologies report regarding characterization of the Wells G and H environment. The GZA site characterization which follows is based on GZA's field reconnaissance of the habitat surrounding the 60 Olympia Avenue facility in March and September 1990, and information found in the Alliance and Ebasco reports. Wildlife or their signs were observed during a site visit in September 1990. Aquatic invertebrates were collected with a dip net from the Aberjona River and from ponded water within wetland. Sampling locations for the aquatic invertebrates are shown on Figure 4. The aquatic invertebrates were identified by Dr. Douglas Smith, curator of the University of Massachusetts Zoology Museum. Mr. Smith was the first to describe the Mystic Valley amphipod, a species of special concern in Massachusetts. This amphipod has been collected in wetlands along the Aberjona River north of the Wells G and H site. Photographs of the habitat surrounding the Olympia Avenue facility are presented in Appendix M. The common and latin names of plants and wildlife observed during GZA's field reconnaissance are listed in Tables 30 and 31, respectively. Fish known to live in the Aberjona River Drainage Basin are listed in Table 32.

The site is part of a heavily industrialized area within the Aberjona River drainage basin. The Industriplex Superfund Site lies approximately 1 mile to the north, and Wells G and H are located south (downgradient) of the site. Local groundwater flow appears to be west, southwest and south. The nearest environmental receptor in the path of groundwater flow is the Aberjona River and surrounding wetlands.

Aberjona River

The Aberjona River drainage basin is part of the Mystic River drainage basin. The Aberjona River originates in wetlands within the town of Reading and flows south through Woburn into Winchester where it drains into Upper Mystic Lake. A large part of the Aberjona River Basin has been subject to industrial development which has contributed to water quality problems.

The Aberjona River is designated as Class B waters by the DEP Division of Water Pollution Control. This classification is goal-oriented and is not indicative of the present water quality. According to the Non-Point Source Assessment Report (Appendix IV, Commonwealth of Massachusetts, Division of Water Pollution Control, Summary of Water Quality, 1989), the water use classification of the river is not supported due to water quality problems. These problems are identified as high levels

of ammonia, coliform bacteria, and metals, and low levels of dissolved oxygen, resulting primarily from storm sewers, surface runoff, industrial land treatment, and highway maintenance and runoff.

A channelized portion of the Aberjona River flows south along the western border of the 60 Olympia Avenue site. Stormwater from Olympia Avenue and the 60 Olympia Avenue parking lot discharges to this reach of the river (stormwater discharge points are referred to as floodgates on Figure 4). The Aberjona River flows onto the site through a concrete box culvert under Olympia Avenue. From this point, the river is channelized for approximately 400 feet after which it widens into a 36-acre wetland south of the property. The river diverges into webs of smaller rivulets in some areas, converges, diverges again, and so on as it winds through the wetland. The channelized portion of the Aberjona adjacent to the 60 Olympia Avenue facility was approximately 17 feet wide and 2 to 3 feet in depth with a flow on March 13, 1990 of about 17 cubic feet per second.

According to the 1987 Alliance Technologies report, the 100-year floodplain of the Aberjona River near the site is between elevation 47 and 49 feet above Mean Sea Level. Therefore, all but the paved portion of the site is inundated during a 100-year flood.

Cover Types and Flora

Wetlands on and surrounding the site are classified on the U.S. Fish and Wildlife Service National Wetland Inventory Map for the Wilmington Quadrangle as palustrine broad-leaved deciduous scrub shrub wetland/emergent wetland to the south of the 60 Olympia Avenue paved parking area and palustrine broad-leaved deciduous forested wetland east of the paved parking area.

The channelized portion of the Aberjona River on the west side of the site is lined with red maples and the shrub, European buckthorn. West of this narrow riparian corridor is a secondary growth upland forest/open field comprised of quaking aspen, gray birch, oaks, white pine, and red maple trees; the shrubs, sheep laurel and European buckthorn; and an herbaceous layer of upland grasses and goldenrod (Photograph 2).

South and southwest of the 60 Olympia Avenue facility, where the river is no longer channelized, it flows through an extensive area of shallow marsh (emergent wetland) dominated by tussock sedge, broad-leaved cattail, common reed, and purple loosestrife (Photographs 3 through 6) with patches of shrub swamp (scrub shrub wetland) (see Figure 4).

At the rear of the trucking facility, south of the pavement and chainlink fence, is an upland peninsula of oak forest surrounded by shallow marsh to the west

and south, and red maple swamp (broad-leaved deciduous forested wetland) to the east. The oak peninsula is shown in Photographs 7 and 8. Species in the understory include European buckthorn, gray birch, American hazelnut, choke cherry, grape, and the herbs wintergreen and bracken fern.

East of the oak peninsula and south of the parking lot is red maple swamp. This forested swamp borders on the large marsh/shrub swamp to the south (Photograph 9). The red maple canopy is fairly sparse over this area (20 percent to 30 percent coverage), and most of the trees have a diameter at breast height (dbh) of approximately 6 to 8 inches. Shrub species such as European buckthorn and swamp dogwood, sheep laurel, arrowwood and highbush blueberry are present throughout the area; these shrubs are often found as patchy clusters. Because the tree layer is fairly sparse and the shrub layer is patchy, the herbaceous layer is quite dense, comprised of species such as tussock sedge, cinnamon fern, sensitive fern, spotted jewelweed, and dodder (Photograph 10). Some snags (dead trees) which can be used for nesting habitat by some birds and mammals were present in the area (approximately 6 inches dbh) (Photograph 11). The swamp area also contains shallow pools of open water in the spring.

Off the southeast corner of the parking lot slope is a concrete headwall and outfall from which stormwater runoff discharges (Figure 4). Probably due to siltation and altered hydrology tall reed is abundant in the area of red maple adjacent to this outfall (Photograph 12).

The red maple swamp continues east of the 60 Olympia Avenue property. This mature forested swamp vegetation is interspersed with small pockets of ponded water in the spring. Dominant understory shrubs are winterberry, swamp dogwood, speckled alder, and witherod. Cinnamon fern, skunk cabbage and sphagnum moss are common in the herbaceous layer (Photograph 13). In March, rust-colored standing water was present in the swamp at the toe of the slope of the parking area along the southeastern property line (Photograph 14). This coloration may have been due to a localized proliferation of iron bacteria.

The red maple swamp grades into an upland oak forest northeast of the property. Understory species include black cherry, American hazelnut, sheep laurel, bracken fern and the upland sedge, Carex pensylvanica. Some of the oaks in the overstory were relatively large, with diameters of approximately 1.5 feet at breast height.

Fauna

According to the Massachusetts Natural Heritage and Endangered Species Program, no state-listed rare wetlands wildlife habitat is present in the vicinity of the site. However, the Mystic Valley amphipod (Crangonyx aberrans), a

Massachusetts species of special concern, has been found in reaches of the Aberjona River north of Route 128. Douglas Smith, Curator of Invertebrates, Museum of Zoology, University of Massachusetts, first discovered this species of crustacean and believes that the amphipod and an additional Massachusetts species of special concern, the intricate fairy shrimp (*Eubbranchipus intricatus*) could be found in wetlands of the Aberjona River south of Route 128. The amphipod and intricate fairy shrimp are found in cool, shallow, slow moving water or vernal pools with leaf litter. Bordering vegetated wetlands in which water is usually present, provide the optimal habitat.

Two areas within the Aberjona River (similar to sample locations X-9 and X-11 of Alliance Technologies) and six pools or drainage areas within the swamp were sampled in early September 1990 by GZA for aquatic invertebrates using a dip net. Sample locations are shown on Figure 4. Sample 1, the "upstream" river sample is used as a reference for sample 2, the "downstream" river sample. Swamp sample locations 5 and 6 were off-site in wetland that was upgradient of any influence of contaminants from the 60 Olympia Avenue site. Results from these samples were used as a reference for the site swamp samples, 3 and 4. The invertebrate samples were sent to Douglas Smith of the University of Massachusetts for identification. Of particular concern was the presence of any potential state-listed rare or endangered species, or species of special concern, such as the Mystic Valley amphipod and the intricate fairy shrimp.

Table 31 lists the invertebrate species collected. No rare wetlands species were identified. In general, species collected in the reference and site samples were similar. Major groups of invertebrates collected in the river included crustaceans (amphipods, isopods and crayfish); and in the swamp the crustaceans (isopods and amphipods), mollusks (pill clams, freshwater snails, and a land snail), and aquatic insects (darners, damselflies, water striders, caddisflies, and crane flies).

No fish were sighted in the Aberjona River during the GZA invertebrate sampling, nor were any observed during Alliance Technologies site investigation; however, Alliance did not specifically sample for fish. The Massachusetts Division of Fisheries and Wildlife does not have information specific to the fish composition of the Aberjona River, a warm water fishery, but does have information regarding fish present in the Aberjona River Basin. The thirteen most abundant species are listed in Table 32. The Fisheries and Wildlife representative expressed doubt that any of these species were present in the vicinity of 60 Olympia Avenue.

The Aberjona River, bordering marsh and swamp, and upland areas on the 60 Olympia Avenue property provide cover and food for a wide array of vertebrates. Wildlife and their signs were observed by GZA during the September field reconnaissance. These observations included gray squirrel in the tree stratum, an 8-inch-diameter woodchuck burrow, virginia opossum tracks, white-tailed deer tracks, and signs of deer and eastern cottontail browse of the woody vegetation.

Mammals or wildlife signs observed by Alliance Technologies included woodchuck burrows, raccoon tracks, and gray squirrels and eastern chipmunks (Tamias striatus) in the tree stratum.

Alliance Technologies also observed reptiles and amphibians in the area, including eastern painted turtles (Chrysemys p. picta), garter snakes (Thamnophis s. sirtalis), snapping turtles (Chelydra serpentina), bullfrogs (Rana catesbiana) and green frogs (Rana clamitans melanota).

7.43 Risk Assessment Endpoints

The ecological risk assessment endpoint is evidence that impacts to plants and animals in the vicinity of the 60 Olympia Avenue facility may have occurred as a result of VOCs from the study site or regional chlorinated VOCs and semi-volatiles incurred by the Aberjona River and its bordering wetlands over time. Impacts to aquatic and benthic organisms are extrapolated by comparing concentrations of VOCs and SVOCs in Aberjona River sediment, VOCs in surface water and wetland soil, and estimated concentrations of VOCs in the Aberjona River surface water that would result from the discharge of site groundwater (see Table 33) to appropriate toxicity information (e.g., USEPA Ambient Water Quality Criteria and Equilibrium Partitioning Interim Sediment Quality Criteria). This information is presented as hazard indices or quotients to provide a means of measuring the magnitude to which measured contaminant concentrations exceed those values shown to cause adverse effects.

7.44 Exposure Assessment

The purpose of the ecological exposure assessment is to evaluate the possible routes by which receptors (the wetlands and their biota discussed in Section 7.42) may come into contact with the contaminants of concern; and the concentrations of these contaminants to which they may be exposed. Information on exposure is used in conjunction with toxicological effects data (Section 7.45) to characterize ecological risk (Section 7.46).

Components of the exposure assessment include characterization of the sources of petroleum associated and chlorinated VOCs, semi-volatiles, and MTBE; environmental transport media (i.e., surface water, groundwater, and sediment); and exposure concentrations and pathways or routes by which individual, population, community or ecosystems may encounter these contaminants of concern.

Sources

Contaminant concentrations in site media cannot be solely attributable to the 60 Olympia Avenue site. Off-site sources of contaminants include Olympia Avenue stormwater runoff which discharges to the Aberjona River at the northern end

of the site, and upgradient contaminated soil, sediment and groundwater that is transported to the reach of the Aberjona River and wetlands abutting the site.

On-site sources of contamination include groundwater and parking lot runoff which discharges to the Aberjona River through an outfall at the northwestern corner of the property and discharges to wetlands through an outfall at the southeastern corner of the site (Figure 4).

Fate and Transport

Once groundwater containing VOCs discharges to surface water, VOC levels decrease through processes such as volatilization, dilution, adsorption, and biodegradation. Volatilization is the primary pathway in the fate of most VOCs, and they generally have a low residence time in surface water. VOCs do not significantly adsorb to sediment or bioconcentrate in aquatic organisms. Several soil and aquatic microorganisms can utilize some VOCs as a carbon source (Moore and Ramamoorthy, 1984).

MTBE is highly soluble in water, therefore, it travels faster than other gasoline components e.g., benzene, toluene, and xylene, and will volatilize readily from surface waters. Little adsorbs onto soil or sediment particles. Available data suggest that MTBE will not bioaccumulate in fish or the food chain.

The behavior of semi-volatile PAHs in the environment varies according to size, and chemical and physical properties. These compounds range from being relatively volatile and soluble, as in the case of naphthalene (the only PAH detected in site groundwater), to having very low volatility and solubility, as in the case of benzo(a)pyrene. PAH compounds, in general, have a relatively high affinity to adsorb or partition to organic media. In water, PAHs may either evaporate, disperse, become incorporated into the bottom sediments, concentrate in the biota, or undergo chemical oxidation or biodegradation. The ultimate fate of PAHs that accumulate in sediments is believed to be biotransformation and biodegradation by benthic organisms (EPA, 1980). However, degradation may proceed very slowly in the absence of sunlight and oxygen. Because PAHs are rapidly metabolized, in general, they show little tendency to biomagnify in food chains, despite their high lipid solubility.

Distribution

VOCs associated with site and regional contamination are highest in the groundwater and at lower levels in the soil, sediment and surface water.

Aromatic VOCs, chlorinated VOCs and one polynuclear aromatic hydrocarbon, naphthalene, were detected in the groundwater (Table 10). The only VOC detected in the groundwater at a concentration exceeding its USEPA Ambient

Water Quality Criteria (AWQC) for surface water was the polynuclear aromatic hydrocarbon, naphthalene. For comparative purposes those detected volatile organics without AWQC were compared to the lowest AWQC for VOCs (500 ppb). Aromatic VOCs in groundwater exceeding this criterion include 1,3,5-trimethylbenzene, o-xylenes, and p&m-xylenes. Chlorinated VOCs detected in groundwater at concentrations exceeding 500 ppb include: cis-1,2-dichloroethene and 1,2,4-trichlorobenzene.

Only the chlorinated VOCs (1,1-dichloroethane, cis-1,2-dichloroethene, and TCE) were detected in the Aberjona River surface water. All three of these compounds were detected in site groundwater. However, because the low VOC levels detected in surface water were similar in upstream (SW-1) and downstream samples (SW-2), the VOCs detected in the surface water are only partially attributed to the discharge of site groundwater.

Projected surface water concentrations were calculated based on measured concentrations of contaminants detected in site groundwater divided by an estimated low flow dilution factor (250). These projected downstream concentrations are reported in Table 33. The projected levels of VOC are quite low, all falling at or below 0.02 $\mu\text{g/l}$.

Two sediment samples from the river (RS-1 and RS-2) were analyzed for VOCs. VOCs detected in the downstream sediment contained acetone (430 $\mu\text{g/kg}$), and methyl-t-butyl ether (100 $\mu\text{g/kg}$), a gasoline constituent (Table 14). These contaminants were not detected in the site groundwater. Therefore, sources might include parking lot stormwater runoff, roadway runoff, or sediment transport from upstream.

The aromatic VOC, toluene, was detected at low levels (5.3 $\mu\text{g/kg}$) in wetland soil (SS-2) from the tall reed stand near the parking lot stormwater outfall. Toluene is a constituent of gasoline and the levels detected in wetland soil probably resulted from stormwater runoff from the parking lot of the trucking facility. No VOCs were detected in wetland soil sample (SS-1) located south of the facility in an area of tussock sedge within the red maple swamp.

The PAHs contamination detected by Ebasco Services (1988) was much higher in sediment samples taken north of Olympia Avenue (Table 15), and have no identified on-site source.

Exposure Pathways

Aquatic organisms in the Aberjona River and wetlands may be exposed to site contaminants through contact with contaminated water, river sediment, wetland soil, and contaminated food.

Plants may be exposed to contaminants through contact with the air, water and soil.

Vertebrates (e.g., amphibians, reptiles, birds, and mammals) may be exposed through the ingestion of contaminants in water, sediment, soil or food items such as plant material or aquatic invertebrates.

7.45 Toxicity Assessment

The toxicity of the measured and predicted VOCs in the surface water of the Aberjona River was assessed using the USEPA AWQC for the protection of freshwater aquatic life (Tables 13 and 33, respectively). The toxicity of VOCs in the river sediment and wetland soil was assessed by comparing measured concentrations of VOCs to calculated Sediment Quality Criteria (SQC) (Tables 14 and 16, respectively). Levels of PAHs in site river sediment were below calculated SQC based on an average sediment organic carbon content of 18 percent (Ebasco Services, 1988). Because methods used to determine the total organic carbon content of sediments may give different results and the distribution of PAHs between the particle bound and aqueous phases are highly influenced by the amount of organic carbon in the sediment, the SQC were recalculated using a more conservative (i.e., more protective of aquatic life) organic carbon content of 1 percent. In addition, the toxicity of PAHs in river sediment was assessed by comparing measured concentrations to recent NOAA sediment biological effects values (Long and Morgan, 1990) (Table 15).

The NOAA effects levels have been developed from an existing database of information regarding the toxic effects of contaminated sediments on aquatic biota. These thresholds are reported in terms of Effects Range-Low (ER-L), Effects Range-Median (ER-M) and Overall Apparent Effects Thresholds (AET). The ER-L refer to the lower 10th percentile of sediment contaminant concentrations associated with adverse biological effects, the ER-M refers to the median value. Overall AET were subjectively identified for those compounds having concentrations above which effects usually or always occurred in association with increasing concentrations of the chemical, and are independent of the ER-L and ER-M values (Long and Morgan, 1990).

The estimated Sediment Quality Criteria is the concentration of a compound in sediment that ensures the concentration in the interstitial water does not exceed the US EPA AWQC or other appropriate toxicological endpoints gathered from the US

EPA QSAR ecotox database (Long and Morgan, 1990). This method uses physical/chemical principles to predict the chemical concentrations that would occur in the interstitial water in equilibrium with those concentrations of chemicals sorbed to particulates in the sediment, recognizing that the distribution of the chemicals between the two phases is highly influenced by the amount of organic carbon present in the sediment.

A brief description of the general toxicity of the contaminants of concern is provided below.

Most VOCs are moderate to slightly toxic to aquatic algae. Increasing substitution leads to enhanced toxicity to many algae. The majority of VOCs do not significantly concentrate in fish or other aquatic species and thus pose little or no threat to fisheries and other forms of aquatic resource utilization (Moore and Ramamoorthy, 1984). Unsubstituted compounds such as benzene and toluene generally exhibit low toxicity. More highly substituted compounds are much more toxic to invertebrates and fish.

The limited toxicity data for MTBE indicate that it is not very toxic. The only toxicity information available on the QSAR database was an LC50 for the fathead minnow (*Pimephales promelas*) of 706,000 ppb. MTBE does not contain structural features which are regarded as highly toxic to algae or aquatic plants.

PAH compounds in the molecular weight range from naphthalene (MW 128) to fluoranthene and pyrene (MW 202) are acutely toxic to aquatic organisms; higher weight PAHs have solubilities below the aqueous concentrations required to produce a response (Gehrs, 1978). PAHs do not readily undergo chemical reactions with cellular biochemical. It is their metabolites, which are more hydrophobic, reactive, and electrophilic, that may undergo a variety of spontaneous or enzyme-mediated chemical reactions that may lead to cellular damage, mutagenesis, teratogenesis, and cancer (Neff, 1985). Depending on the type and concentration, PAHs may stimulate or inhibit the growth of bacteria or plants. At high concentrations, most PAHs are acutely toxic to plants by reducing cell division rates, inhibiting photosynthesis, or killing cells outright. The toxicity to plants tends to increase with higher molecular weight.

7.46 Risk Characterization

To quantify risk associated with the contaminants of concern, hazard indices were calculated by dividing the concentration of the contaminant by the chronic and acute AWQC, SQC, or NOAA Effects Range-Low values. Hazard indices greater than one indicate that an effects threshold is exceeded.

Ecological risk assessment hazard indices for contaminants attributable to the trucking facility are very low. River surface water, sediment and wetland soil hazard indices for VOCs are reported in Tables 13, 14 and 16, respectively. VOCs in river surface water are well below USEPA AWQC. In addition, surface water (Aberjona River) concentrations of compounds predicted from site groundwater concentrations were compared to USEPA AWQC for surface waters (DEP, 1986). None of the predicted surface water concentrations exceeded their applicable AWQC (Table 33). VOCs detected by GZA and PAHs detected by Ebasco in river sediment were below their calculated SQC.

PAHs in river sediment exceed NOAA ER-L values (Table 34). PAHs detected in site sediment are believed to have an upstream source. Only one PAH, naphthalene, was detected in the site groundwater; none was detected in the site river sediment.

Toluene, the only VOC detected in site wetland soil, was well below its calculated SQC.

7.47 Ecological Risk Assessment Summary

No potential impacts to aquatic life or terrestrial wildlife were identified due to the presence of petroleum constituents and VOCs presently associated with the Olympia Nominee Trust site. Aquatic invertebrates collected with a dip net from upstream and downstream of the site in the Aberjona River and upgradient and downgradient of the site in adjacent wetlands were similar (see Section 7.41). Potential impacts to aquatic life previously identified by Ebasco Services (1988) were due to the presence of lead in the surface water and metals in the river sediment downgradient of the site. PAHs detected by Ebasco Services (1988) in river sediment adjacent to the site may pose an increased risk to aquatic life associated with sediment. These PAHs have no presently identifiable on-site source, and the higher concentrations of PAHs detected upstream of the site suggest an off-site source. Potential chronic risks to terrestrial birds and mammals from the consumption of soil invertebrates were identified by Ebasco Services (1988) and associated with the presence of DDT, PAHs and PCBs in site soils. No risks were identified due to the presence of site associated petroleum constituent and VOCs. Similarly, our findings suggest that VOC levels detected in site wetland soil pose little risk to terrestrial wildlife populations.

In summary, site associated petroleum hydrocarbon constituents and VOCs detected in site river water, sediment and wetland soil do not pose a significant threat to the wildlife and vegetation of the adjacent Aberjona River and wetland based on current toxicological information.

7.48 Uncertainty

A level of uncertainty is inherent in any ecological risk assessment. For example, measuring toxicity by ratio to benchmarks (AWQC for water, SQC for sediment) is valid, but limited: it does not allow a measure of risk to especially sensitive species, or consider the possible adverse effects of long-term exposure. In addition, the present approach does not account for interactions between chemicals found at this site.

8.00 SUMMARY AND CONCLUSIONS

GZA has completed a Phase II - Comprehensive Site Investigation, as defined in the Massachusetts Contingency Plan, of the Olympia Nominee Trust property at 60 Olympia Avenue in Woburn, Massachusetts. The study included a review of previous reports, a soil gas survey, installation of four additional shallow monitoring wells and two deep monitoring wells, collection and chemical analysis of soil, groundwater, surface water, and sediment samples, hydraulic conductivity testing of site soils, evaluation of hydrogeologic properties of the overburden materials at the site, review of contaminant properties, evaluation of contaminant distribution, and a public health and environmental risk characterization. The work was conducted in accordance with a work plan and subsequent modifications required and approved by the DEP. Based on the information developed during the Phase II study, GZA has reached the following conclusions:

1. The Olympia Nominee Trust site has been used as a trucking terminal since approximately 1963. Underground storage tanks for petroleum products have been located at the site since 1963; several tanks formerly at the site have been removed. Several tanks were removed from the site in 1987, and approximately 350 cubic yards of contaminated soil. At the time of removal of the tanks, floating (separate phase) petroleum product was observed by Hidell-Eyster Technical Services, Inc. in the excavation. Petroleum constituents have been detected in groundwater monitoring wells installed in the vicinity of the current and former underground storage tanks.
2. The 60 Olympia Avenue site is within the boundaries of the Wells G and H federal Superfund site, as defined by the U. S. EPA. The EPA and parties potentially responsible for contamination at the Wells G and H site have conducted a number of studies of the area around Wells G and H to characterize the source, nature and extent of contaminants in the area, and to develop potential remedial action alternatives. These studies focused on chlorinated VOCs; petroleum constituents were not found to be widely distributed in the area surrounding Wells G and H.

3. A soil gas survey conducted by GZA indicated the presence of chlorinated VOCs, primarily TCE and PCE, in 21 of the 29 samples obtained. The source of these materials has not been specifically identified. Although some of the chlorinated VOCs may be from an on-site source, these compounds are the main VOCs identified in the Wells G and H studies, and may represent the impacts of regional contamination. Petroleum constituents were detected at 9 of the 29 soil gas sampling locations, mainly in the immediate vicinity of the 1987 tank excavation area.
4. VOCs associated with petroleum products were either not detected or were present at only low concentrations in soil samples collected during the Phase II study. Studies conducted at the site by GZA in 1985 and 1988 indicated the presence of gasoline constituents in soils from borings B-2, GZ-1, and GZ-3, based on GC screening.
5. Results of analyses of groundwater samples collected from the monitoring wells installed as part of the Phase II study did not indicate the presence of substantial quantities of petroleum-associated compounds. However, petroleum constituents were detected at elevated concentrations in groundwater from well MW-1, installed by Hidell-Eyster Technical Services in an area in which floating product had been observed. Chlorinated VOCs were detected in most of the groundwater samples, including samples from the deep borings GZ-11 and GZ-12. The chlorinated compounds detected in samples from the deep wells are presumed to be from off-site sources.
6. Subsurface materials at the site consist of fill material overlying a fine to coarse sand layer which overlies a thick silty-sand unit. Casing and split-spoon refusal, presumed to be on the top of bedrock, was encountered in deep borings GZ-11 and GZ-12 at depths of approximately 65 feet. Several inches of till were recovered from just above refusal in these borings.
7. The direction of groundwater flow beneath most of the site is southwesterly toward the Aberjona River. In the northwestern corner of the property, groundwater flow is westerly or northwesterly, and appears to be influenced by sewer lines in this area.
8. Potential receptors of groundwater from the 60 Olympia Avenue property include the Aberjona River, and, if they were to be re-activated, Woburn municipal Wells G and H. Pump test data indicate that the two municipal wells, when operating, induced a significant amount of infiltration from the Aberjona River; specific information concerning the influence of these wells on the area of the 60 Olympia Avenue is not available. Dilution factors calculated by GZA for groundwater discharging from the site indicated that concentrations of contaminants related to the 60 Olympia Avenue site would be well below

acceptable drinking water standards at Wells G and H if the wells were to be re-activated.

9. Two potential receptor groups, adult construction workers and area residents, were identified as part of GZA's health risk assessment. Assuming that these groups would directly contact soil and inhale soil gas, or ingest, inhale, and dermally contact groundwater, and directly contact and incidentally ingest surface water, respectively, total site hazard indices and total site cancer risks were calculated. The results indicated that the site poses risks below acceptable public health risks levels regarding both non-carcinogenic and carcinogenic effects for both receptor groups. As none of the risks estimated for the two identified potential receptor groups exceeded DEP acceptable risk levels, development of cleanup goals for on-site media, and subsequent remediation, is not required.
10. The 60 Olympia Avenue facility poses risks well below toxicological benchmarks for the protection of vegetation and wildlife in the vicinity of the site. PAH levels in the site river sediment are of potential concern; however, available data indicate that the facility does not represent the source of these contaminants. Therefore, the development of cleanup goals for on-site media (soil and groundwater) and subsequent remediation, is not required for protection of bordering vegetated wetlands.

9.00 RECOMMENDATIONS

As noted in Sections 7.00 and 8.00, results of the human health and environmental risk assessments indicate that the site poses risks below acceptable public health and environmental risk levels, and that development of cleanup criteria and subsequent remediation are not required.

GZA notes that separate phase (floating) petroleum product was detected at well MW-1 during the Phase II study, and had been detected at this location during earlier studies. The floating product is a continuing source of groundwater contamination at the study site. It is our understanding that a gravel-filled trench and associated piping which could be used as part of a product recovery system were installed at the site in 1987 following the removal of underground storage tanks. Although GZA's risk characterization results do not indicate that remediation is required at the 60 Olympia Avenue site, GZA recommends removal of the floating product layer in the vicinity of well MW-1.

REFERENCE LIST

- Alliance Technologies Corporation, Well G and H Wetlands Assessment, March 1987, U.S. EPA Contract No. 68-01-7037, Massachusetts.
- Ebasco Services, Inc., Endangerment Assessment for the Wells G&H Site, Woburn, Massachusetts, December 1988, EPA Contract, No. 68-01-7250, New Jersey.
- Gehrs, C.W., 1978, Environmental implications of coal conversion technologies: organic contaminants. In: Energy and Environmental Stress in Aquatic Systems, eds.: J.H. Thorpe, J.W. Gibbons, pp 157-175. CONF-771114, Springfield, Va.: National Technical Information Center, 1978.
- Goldberg-Zoino & Associates, Inc., Environmental Assessment for 60 Olympia Avenue, February 6, 1985, Newton, Massachusetts.
- Goldberg-Zoino & Associates, Inc., Hydrogeologic Assessment for 60 Olympia Avenue, Woburn, Massachusetts, October 1988, Newton, Massachusetts.
- Goldberg-Zoino & Associates, Inc., Soil Gas Survey and Proposed Boring Locations at 60 Olympia Avenue, Woburn, Massachusetts, October 18, 1989, Newton, Massachusetts.
- Hydell Eister Technical (HET) Services, Inc., Tank Removal Report, November 1987, Accord, Massachusetts.
- Long, E. and L.G. Morgan, 1990, The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52.
- Massachusetts Department of Environmental Protection (DEP), 1989, Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan. Office of Research and Standards, May 17, 1989.
- Massachusetts Department of Environmental Protection (DEP), Surface Water Quality Standards, 314 CMR 4.00, Bureau of Resource Management.

- Massachusetts Department of Environmental Protection (DEP), Appendix IV --
Non-Point Source Assessment Report, 1989, Summary of Water Quality,
Division of Water Pollution Control.
- Massachusetts Department of Environmental Protection (DEP), Office of Research
and Standards, Massachusetts Drinking Water Standards and Guidelines,
October 1990.
- Massachusetts Division of Fisheries and Wildlife, 1990, Atlas of Estimated Habitats
of State-listed Rare Wetlands Wildlife. Natural Heritage and Endangered
Species Program.
- Moore J.W. and S. Ramamoorthy, 1984, Organic Chemicals in Natural Waters Applied
Monitoring and Impact Assessment. Springer-Verlag, New York. 289pp.
- Neff, J.M., 1985, Polycyclic Aromatic Hydrocarbons, Chapter 14 in Fundamentals of
Aquatic Toxicology, Eds: G.M. Rand and S.R. Petrocelli, Hemisphere
Publishing Corp., New York, 666 pp.
- U.S. Environmental Protection Agency (USEPA), 1980, Ambient Water Quality
Criteria for Polynuclear Aromatic Hydrocarbons. EPA Report No. 440/5-80-
069, 193pp.
- U.S. Environmental Protection Agency (USEPA), 1986, Ambient Water Quality
Criteria.
- U.S. Environmental Protection Agency (USEPA), Region I, Priority Wetlands in
New England, 1987.
- U.S. Environmental Protection Agency (USEPA), 1988, Review of Ecological Risk
Assessment Methods. EPA/230/10-88/041. Office of Policy Analysis and
Office of Policy, Planning and Evaluation. U.S. Environmental Protection
Agency, 401 M Street, SW, Washington, D.C.
- U.S. Environmental Protection Agency (USEPA), Region 1, February 1989a, Draft
Final Risk Assessment Guidance. Part I - Supplemental Guidance on
Superfund Public Health Risk Assessments.
- U.S. Environmental Protection Agency (USEPA), Region 1, February 1989b, Draft
Final Risk Assessment Guidance, Part 2 - Guidance for Ecological Risk
Assessments, USEPA Region 1 Risk Assessment Work Group, Boston,
Massachusetts.
- U.S. Environmental Protection Agency (USEPA), March 1989a, Risk Assessment

Guidance for Superfund Volume II Environmental Evaluation Manual. EPA 540/1-89/001. Office of Emergency and Remedial Response. USEPA, Washington, D.C.

U.S. Environmental Protection Agency (USEPA), March 1989b, Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. EPA/600/3-89/013. Environmental Research Laboratory. Corvallis, Oregon.

U.S. Environmental Protection Agency (USEPA), July 1989, Exposure Factors Handbook. Office of Health and Environmental Assessment. Washington, D.C.

U.S. Environmental Protection Agency (USEPA), July 1989, Health Effects Assessment Summary Tables (HEAST), Office of Health and Environmental Assessment. Cincinnati, Ohio. Third/fourth quarter.

U.S. Environmental Protection Agency (USEPA), December 1989, Risk Assessment Guidance for Superfund - Volume 1 - Human Health Evaluation Manual (Part A). Interim Final Office of Emergency and Remedial Response. Washington, D.C.

U.S. Environmental Protection Agency (USEPA), April, May 1990, Integrated Risk Information System (IRIS). Chemical files.

U.S. Environmental Protection Agency (USEPA), February 1991, Summary Report on Issues in Ecological Risk Assessment. EPA/625/3-91/018. Risk Assessment Forum. USEPA, Washington, D.C.

U.S. Department of the Interior, Fish and Wildlife Service, 1977, National Wetland Inventory Map for the Wilmington, Massachusetts Quadrangle.

TABLE 5 (CONT.)

<u>BORING NUMBER</u>	<u>SAMPLE NUMBER</u>	<u>SAMPLE DEPTH (feet)</u>	<u>LABORATORY PID READING</u>
GZ-12	S-1	0.8-2.8	ND
	S-2	5-7	0.4
	S-3	10-12	ND
	S-4	15-17	0.1
	S-5	20-22	ND
	S-6	25-27	ND
	S-7	30-32	ND
	S-8	35-37	1.0
	S-9	40-42	0.8
	S-10	50-52	0.2
	S-11	55-57	0.4
	S-12	64-65.7	0.2

Notes:

1. Laboratory testing data represent total organic vapor levels, referenced to a benzene standard, measured in the headspace of sealed soil sample jars using an H-Nu Model PI-101 photoionization analyzer. Results are in parts per million (ppm). ND denotes none detected (<0.1 ppm). Testing was performed at GZA's Newton Environmental Chemistry Laboratory between January 2 and 6, 1990.
2. A dashed line (--) indicates that the soil sample was screened for volatile organic compounds by EPA Method 8240 at GZA's Newton Laboratory; see Table 6 for 8240 results.

TABLE 6

RESULTS OF METHOD 8240 ANALYSES OF SOIL SAMPLES

BORING NUMBER	GZ-7	GZ-8	GZ-9	GZ-10	GZ-11
SAMPLE NUMBER	S-4	S-2	S-1	S-3	S-3
SAMPLE DEPTH (FT)	15-17	5-7	0.8-2.8	10-12	10-12
TOTAL 1,2-DICHLOROETHENES	ND	ND	ND	ND	13
TRICHLOROETHENE	8.4	ND	ND	ND	ND
BENZENE	ND	ND	ND	ND	13
TETRACHLORETHYLENE	10	ND	ND	ND	ND

Notes:

1. Results in $\mu\text{g/kg}$ (parts per billion). ND denotes none detected. Refer to laboratory report for individual detection limits.
2. Samples collected by GZA personnel on January 1-4, 1990.
3. Samples analyzed by EPA Method 8240 at GZA's Environmental Chemistry Laboratory in Newton, Massachusetts on January 3-4, 1990.
4. Only detected compounds are listed above. Refer to laboratory reports for complete list of compounds analyzed.

[illegible]

TABLE 7 (CONT'D)

Notes

1. See Figure 2 for monitoring well locations.
2. Results in $\mu\text{g/L}$ (parts per billion); laboratory detection limit is $0.5 \mu\text{g/L}$ unless otherwise indicated in laboratory report. Blank spaces indicate none detected.
3. Samples collected by GZA personnel on January 10, 1990 with the exception of MW-1 and MW-2, which were collected on March 15, 1990.
4. Samples analyzed by EPA Method 524.2 at Water Control Laboratories in Hopkinton, Massachusetts, January and March, 1990.
5. Only detected compounds are listed above. Refer to laboratory reports (Appendix J) for a complete list of compounds analyzed.

TABLE 8

SUMMARY OF PETROLEUM HYDROCARBON (PHC) AND BASE/NEUTRAL (PAH) COMPOUND
CONCENTRATIONS IN GROUNDWATER SAMPLES

STATION	PHC-IR (EPA METHOD 418.1)	PHC-FINGERPRINT (MODIFIED ASTM METHOD D3388)	EPA METHOD 8270 PAH (ppb)
GZ-1	ND	N/A	ND
GZ-3	ND	N/A	N/A
GZ-3 DUP	ND	N/A	N/A
GZ-4	ND	N/A	N/A
GZ-5	2.0	0.26	N/A
GZ-11	ND	N/A	N/A
GZ-12	ND	N/A	N/A
B-3A	ND	0.04	N/A
MW-1	N/A	1,900	240

Notes:

1. Samples were collected by GZA personnel.
2. PHC analyses on all samples except for MW-1 were conducted by Erco Laboratory, Cambridge, Massachusetts (January 1990). PHC analysis on sample MW-1 was conducted by GZA's ECL, Newton, Massachusetts (March 1990); PHC results in mg/L (parts per million).
3. PHC-IR analysis identifies total petroleum hydrocarbon concentrations. PHC-Fingerprint analysis identifies total petroleum hydrocarbon concentrations as well as individual petroleum hydrocarbon compounds. PHC-Fingerprinting analysis identified No. 2 fuel oil (diesel fuel) in monitoring well MW-1; PHC-Fingerprinting results on monitoring well GZ-5 and B-3A were below the compound identification limits.
4. PAH analyses were conducted by Water Control Laboratories, Hopkinton, Massachusetts (March 1990) - EPA Method 8270. PAH results in μ /L (parts per billion). Groundwater sample MW-1 contained 240 ppb naphthalene.
5. N/A indicates not analyzed.
6. ND indicates none detected (refer to laboratory reports for detection limits).

TABLE 9

File No. 4596.2
August 1991

COMPOUNDS EVALUATED IN PHASE II
RISK CHARACTERIZATION
60 OLYMPIA AVENUE SITE

VOLATILE ORGANIC COMPOUNDS (VOCs)
Aromatics:

Acetone*
Benzene
N-Butylbenzene
Sec-Butylbenzene
Tert-Butylbenzene
Ethylbenzene
Isopropylbenzene
P-Isopropyltoluene
Methyl Tert Butyl Ether (MTBE)
Naphthalene
N-Propylbenzene
Toluene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
O-Xylene
P & M Xylenes

Chlorinated:

Chloroform
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
Tetrachloroethene
1,2,4-Trichlorobenzene
Trichloroethene
1,1,2-Trichloroethane
Vinyl Chloride

16 TOTAL PETROLEUM HYDROCARBONS (TPH)

NOTE:

* = Evaluated in the Ecological Risk Assessment only.

TABLE 10

August 1991

SUMMARY OF ANALYTICAL RESULTS
FROM 60 OLYMPIA AVENUE
GROUNDWATER DATA

COMPOUND	FREQUENCY OF DETECTION	RANGE OF DETECTED CONCENTRATIONS (ug/l)	AVERAGE CONCENTRATION (ug/l)	WELL ID. WITH HIGHEST CONCENTRATION (ug/l)
Volatile Organic Compounds (VOC)				
Aromatics:				
Benzene	10 / 19	0.5, 287	3.65	B-2A
N-Butylbenzene	2 / 19	0.7, 1050	27.26	MW-1
Sec-Butylbenzene	1 / 19	0.6	0.44	GZ-2
Tert-Butylbenzene	1 / 19	1.4	0.46	GZ-1 (dup.)
Ethylbenzene	2 / 19	Trace, 12.5	0.52	GZ-1 (dup.)
Isopropylbenzene	3 / 19	0.7, 2.7	0.55	GZ-1 (dup.)
P-Isopropyltoluene	1 / 19	0.7	0.45	GZ-1 (dup.)
Naphthalene	5 / 19	0.6, 4370	0.73	MW-1
N-Propylbenzene	2 / 19	1.3, 5.8	0.54	GZ-1 (dup.)
Toluene	8 / 19	0.5, 5.3	1.59	B-4
1,2,4-Trimethylbenzene	2 / 19	14.0, 61.8	0.59	MW-2
1,3,5-Trimethylbenzene	3 / 19	2.3, 3870	0.61	MW-1
O-Xylenes	8 / 19	Trace, 1880	0.82	MW-1
P&M-Xylenes	7 / 19	0.8, 840	0.87	MW-1
Alkylated Benzenes	NA	NA	3.37	NA
Trimethylated Benzenes	NA	NA	1.2	NA
Chlorinated VOC:				
Chloroform	4 / 19	0.5, 2.5	0.58	GZ-12
1,1-Dichloroethane	2 / 19	1.8, 9.2	0.57	GZ-11
1,2-Dichloroethane	1 / 19	0.5	0.44	GZ-11
1,1-Dichloroethene	2 / 19	0.6, 2.1	0.50	GZ-11
cis-1,2-Dichloroethene	14 / 19	Trace, 2760	2.86	MW-1
trans-1,2-Dichloroethene	2 / 19	2.2, 4.1	0.55	B-2A
Tetrachloroethene	11 / 19	Trace, 520	3.31	MW-1
1,2,4-Trichlorobenzene	1 / 19	5620	0.50	MW-1
Trichloroethene	9 / 19	0.7, 470	1.14	MW-1
1,1,2-Trichloroethane	1 / 19	2.1	0.47	GZ-6
Vinyl Chloride	1 / 19	2.5	0.48	GZ-6
Total Petr. Hydrocarbons:				
Method No. 418.1	1 / 7	(mg/l) 2.0	(mg/l) 1.1	(mg/l) GZ-5
ASTM Method D3328	3 / 3	0.04, 1900	2.7	MW-1

NOTES:

1. Data from samples collected by GZA on 1/90, except for wells MW-1 and MW-2, which were sampled on 3/26/90.
2. Samples collected on 1/90 were analyzed for Volatile Organic Compounds (VOC's) using EPA Method 524, which had a detection limit of 0.5 ug/l. Samples collected on 3/26/90 were analyzed for VOC's using EPA Method 524.2, which had a detection limit of 500 ug/l for Well MW-1, and 10 ug/l for MW-2.
3. Only detected compounds are listed; NA = Not Applicable.
4. Average concentrations were determined using weighted means. One-half of the method detection limit was used to represent concentrations reported as not detected.
5. The average for alkylated benzenes (N, Sec, Tert-Butylbenzenes, Isopropylbenzene, P-Isopropyltoluene & N-Propylbenzene), and for Trimethylated benzenes was calculated using the sum of the individual compounds' geometric means.

TABLE 11

4596.20
March 1991

SUMMARY OF ANALYTICAL RESULTS
FROM 60 OLYMPIA AVENUE
GC SCREENING, GC 8240 ANALYSIS FOR VOC's IN SOILS

COMPOUND	FREQUENCY OF DETECTION	RANGE OF DETECTED CONCENTRATIONS (ug/g)	AVERAGE CONCENTRATION (ug/g)	LOCATION WITH HIGHEST CONCENTRATION (ug/g)	METHOD DETECTION LIMIT (ug/g)
Volatile Organic Compounds (VOC)					
Aromatics:					
Benzene	1 / 8	.013	0.006	GZ-11;S-3	0.01
Ethylbenzene	1 / 8	0.18	0.027	GZ-1;S-3	0.01
Toluene	1 / 8	1.4	0.018	GZ-1;S-3	0.01
M,P-Xylenes	1 / 8	0.08	0.014	GZ-1;S-3	0.01
O-Xylene	1 / 8	0.09	0.015	GZ-1;S-3	0.01
Chlorinated VOC:					
total-1,2-Dichloro-ethenes	1 / 8	0.013	0.0038	GZ-11;S-3	0.005
Tetrachloroethene	1 / 8	0.01	0.0034	GZ-7;S-4	0.005
Trichloroethene	1 / 8	0.084	0.013	GZ-7;S-4	0.005
Other:					
Methyl-t-Butyl Ether	2 / 8	3.6,3.6	0.94	GZ-1;S-2& GZ-3;S-3	0.1

NOTES:

1. Data from samples collected by GZA on April 8, 1988 and January 1-4, 1990.
2. Samples collected on 4/88 were analyzed for Volatile Organic Compounds (VOC's) using the Gas Chromatography Screening Method; concentrations are measured in parts per million (ppm), ug/gram of wet soil.
3. Samples collected on 1/90 were analyzed by EPA Method 8240.
4. Only detected compounds are listed above.
5. Average concentrations were determined using arithmetic means. One-half of the method detection limit was used to represent concentrations reported as "not detected."

TABLE 12
SUMMARY OF ANALYTICAL RESULTS
FROM 60 OLYMPIA AVENUE
SOIL GAS MONITORING RESULTS

4596.20
October 1990

COMPOUND	FREQUENCY OF DETECTION	RANGE OF DETECTED CONCENTRATIONS (ppm)	AVERAGE CONCENTRATION (ppm)	LOCATION WITH HIGHEST CONCENTRATION (ppm)	METHOD DETECTION LIMIT (ppm)
Volatile Organic Compounds (VOCs)					
Aromatics:					
Benzene	8 / 29	Trace, 1.8	0.081	SG-2	0.02
Toluene	9 / 29	Trace, 1.5	0.086	SG-8	0.02
M,P-Xylenes	3 / 29	Trace, 1.6	0.082	SG-8	0.05
O-Xylene	4 / 29	Trace, 1.0	0.061	SG-8	0.05
Chlorinated VOCs:					
Tetrachloroethene	19 / 29	Trace, 10.0	0.65	SG-17	0.02
Trichloroethene	16 / 29	Trace, 7.8	0.44	SG-17	0.02

NOTES:

1. Data from samples collected by GZA on July 13-14, 1989. All samples were collected from a soil depth of approximately 3 feet.
2. Samples were analyzed for Volatile Organic Compounds (VOCs) using a Photovac 10s10 Gas Chromatograph (GC) equipped with heated oven and with a CPSIL-5 capillary column. The concentrations were converted to units of parts per million (ppm) - volume/volume, assuming standard temperature and pressure.
3. Only detected compounds are listed.
4. Average concentrations were determined using arithmetic means. One-half of the method detection limit was used to represent concentrations reported as not detected.

TABLE 13

**SUMMARY OF DETECTED VOLATILE ORGANICS IN SURFACE WATER
OF THE ABERJONA RIVER AT 60 OLYMPIA AVENUE**

COMPOUND	UPSTREAM (ug/l)		DOWNSTREAM (ug/l)		FRESHWATER AWQC (ug/l)		HAZARD INDEX	
	<u>GZA</u>	<u>EBASCO</u>	<u>GZA</u>	<u>EBASCO</u>	<u>CHRONIC</u>	<u>ACUTE</u>	<u>CHRONIC</u>	<u>ACUTE</u>
VOLATILE ORGANICS	<u>SW-1</u>	<u>SW-02</u>	<u>SW-2</u>	<u>SW-03</u>				
Chlorinated:								
cis-1,2-Dichloroethene	1.9	(ND)	1.85	(ND)	NA	11,600	-	1.6E-04
1,1-Dichloroethane	0.5	(2.0)	0.6	(2.0)	20,000	118,000	2.8E-05	4.7E-06
Trichloroethene	1.7	(1.0)	1.75	(1.0)	840	5,280	2.0E-03	3.3E-04
1,1,1-Trichloroethane	ND	(2.0)	ND	(1.0)	9,400	18,000	-	-

Notes:

1. Data in parentheses are from Ebasco Services, Inc. surface water sample stations SW-02 and SW-03, Endangerment Assessment for the Wells G and H Site, Woburn, Massachusetts, December 1988, EPA Contract Number 68-01-7250. GZA surface water data reported in this table is from a 1990 sampling round. An earlier GZA sampling round was conducted May 6, 1988. The surface water samples were GC screened for volatile organics and concentrations were below the detection limit.
2. GZA and Ebasco Services surface water sampling locations are shown on Figure 4.
3. U.S. EPA Ambient Water Quality Criteria for the Protection of Aquatic Life obtained from: Quality Criteria for Water, 1986. United States Environmental Protection Agency, Office of Water, Regulations and Standards, Washington, D.C. EPA 440/5-86-001.
4. Hazard indices are calculated by dividing the average of the GZA upstream and downstream surface water concentrations by the U.S. EPA Ambient Water Quality Criteria.
5. ND = Not detected.
6. NA = No EPA Criteria are available.

TABLES

TABLE 1
SUMMARY OF GROUNDWATER ELEVATIONS

Station Number ¹	Measuring Point Elevation ² (feet)	January 8, 1990		March 26, 1990	
		Depth to Water (feet)	Groundwater Elevation ² (feet)	Depth to Water (feet)	Groundwater Elevation (feet)
B-1	101.71	6.10	95.6	5.64	96.1
B-2A	99.21	4.80	94.4	4.50	94.7
B-3A	100.92	5.64	95.3	5.14	95.8
B-4	99.33	5.62	93.7	5.34	94.0
B-5	100.90	6.62	94.3	6.50	94.4
GZ-1	100.71	5.60	95.1	4.94	95.8
GZ-2	100.67	5.55	95.1	4.98	95.7
GZ-3	100.04	5.13	94.9	4.61	95.4
GZ-4	99.59	4.84	94.8	4.38	95.2
GZ-5	99.26	4.48	94.8	3.87	95.4
GZ-6	99.37	4.45	94.9	3.86	95.5
GZ-7	100.71	5.92	94.8	5.42	95.3
GZ-8	100.24	5.53	94.7	4.98	95.3
GZ-9	99.79	5.31	94.5	4.64	95.2
GZ-10	99.40	4.76	94.6	4.00	95.4
GZ-11	99.38	5.22	94.2	5.15	94.2
GZ-12	100.34	5.65	94.7	5.26	95.1
MW-1	100.48	(3)	(3)	(4)	(4)
MW-2	99.74	(3)	(3)	4.60	95.1

Notes:

1. Refer to Figure 2 for monitoring well locations. Refer to Figure 5 for the groundwater contour plan based on the March 26, 1990 data.
2. Measuring point elevation referenced to an on-site benchmark (northwest corner of MW-2 concrete pad) with an assumed elevation of 100.00 feet; measuring point elevations and depths to water were taken from the tops of PVC riser pipe. Groundwater elevations were calculated by subtracting depths to water from measuring point elevations. Measuring point elevations for monitoring wells GZ-7 through GZ-12 were surveyed on January 15, 1990; all other wells were surveyed as part of GZA's 1988 study.
3. Monitoring wells MW-1 and MW-2 were inaccessible on January 8, 1990.
4. Monitoring well MW-1 was not used in calculating groundwater elevation contours due to the presence of 0.4 feet of floating product.

TABLE 2
SUMMARY OF RISING HEAD PERMEABILITY TEST RESULTS

Monitoring Well ID	Wellscreen Depth from Ground Surface (feet)	Strata Description	Hydraulic Conductivity (K in ft/day)
GZ-7	5-15	5-15': fine to coarse sand	Test 1 = 24* Test 2 = 18* Ave. = 21
GZ-9	3-13	0-5': fill 5-13': fine to coarse sand	Test 1 = 8.3* Test 2 = 7.8 Ave. = 8.0
GZ-11	54.5 - 64.5	20-63': silty sand and silt 63-64.5': till	Test 1 = 1.9 Test 2 = 1.1 Ave. = 1.5
GZ-12	50 - 60	16-63': silty sand and silt 63-66': till	Test 1 = 1.2 Test 2 = 0.7 Ave. = 0.9

Notes:

1. Monitoring wells installed by GZA between January 2 and 8, 1990; see Figure 2 for locations.
2. Rising head tests conducted by GZA between January 8 and 10, 1990 in accordance with Hvorslev (1951). See Section 4.50.
3. Strata description represents thickness of consecutive strata encountered in screened interval of monitoring well. Complete strata descriptions are included on boring logs attached as Appendix F.
4. Hydraulic conductivity (K) calculated using equations derived by Hvorslev (1951) and graphic methods. Numbers shown represent calculations from duplicate test results and an average of duplicate results. Refer to Section 5.00 of text for further explanation.
5. An asterisk (*) indicates that this value was used in calculating an average K value for the site.

TABLE 3
SUMMARY OF LABORATORY HYDRAULIC CONDUCTIVITY TEST RESULTS

Sample Location	Sample Depth Below Ground Surface (feet)	Strata Description	Hydraulic Conductivity (K)	
			cm/sec	ft/day
GZ-7/S-3	10-12	Fine to coarse sand, little gravel, trace (-) silt	6×10^{-2}	170
GZ-9/S-2	5-7	Silt and fine sand	--	--
GZ-9/S-3	10-12	Fine to coarse sand, little gravel, trace (-) silt	9×10^{-3}	25*
GZ-11/S-13	58-60	silt	--	--
GZ-12/S-11	55-57	Silt, some fine sand	--	--

Notes:

1. Refer to Figure 2 for sample locations; complete strata descriptions are included on boring logs attached as Appendix F.
2. Samples collected by GZA between January 2 and 8, 1990.
3. Hydraulic conductivity test data and analyses were generated by GZA's Newton Soil Testing Laboratory on April 4, 1990 using sieve data and the Kozeny-Carmen solution. Refer to text for further explanation.
4. Dashed lines (--) indicate that a K value could not be calculated from available data. Estimates of K for these three samples ranged between 1×10^{-5} to 5×10^{-5} cm/sec (0.03 to 0.1 ft/day).
5. An asterisk (*) indicates that this value was used in calculating an average K value for the site.

TABLE 4
SUMMARY OF PHASE II LABORATORY ANALYSES

<u>Analysis</u>	<u>Sample No.</u>	<u>Matrix</u>	<u>Laboratory</u>	<u>Date</u>	<u>Phase II Report Reference</u>
H-Nu Screen	GZ-7 (all)	Soil	GZA	January 1990	Table 5, Appendix G
	GZ-8 (all)	Soil	GZA	January 1990	Table 5, Appendix G
	GZ-9 (all)	Soil	GZA	January 1990	Table 5, Appendix G
	GZ-10 (all)	Soil	GZA	January 1990	Table 5, Appendix G
	GZ-11 (all)	Soil	GZA	January 1990	Table 5, Appendix G
	GZ-12 (all)	Soil	GZA	January 1990	Table 5, Appendix G
VOC Method 8240	GZ-7 (S-4)	Soil	GZA	January 1990	Appendix H
	GZ-8 (S-2)	Soil	GZA	January 1990	Appendix H
	GZ-9 (S-1)	Soil	GZA	January 1990	Appendix H
	GZ-10 (S-3)	Soil	GZA	January 1990	Appendix H
	GZ-11 (S-3)	Soil	GZA	January 1990	Appendix H
	SS-1	Water	GZA	September 1990	Appendix J
	SS-2	Water	GZA	September 1990	Appendix J
	RS-1	Water	GZA	September 1990	Appendix J
VOC Method 524.2	GZ-1 through GZ-12	Water	Water Control Laboratories	January 1990	Appendix I
	MW-1 and MW-2	Water	Water Control Laboratories	March 1990	Appendix I
	SW-1 and SW-2	Water	Water Control Laboratories	January 1990	Appendix I
	B-1, B-2A, B-3A	Water	Water Control Laboratories	January 1990	Appendix I
	B-4 and B-5	Water		January 1990	Appendix I
PHC - Methods 418.1 and ASTM D3388	GZ-1, GZ-3, GZ-4, GZ-5, GZ-11, GZ-12, B-3A and MW-1	Water	GZA and Water Control Laboratories	January and March 1990	Appendices I and J
PAH Method 8270	GZ-1 and MW-1	Water	Water Control Laboratories	March 1990	Appendix I

TABLE 5
LABORATORY PID SCREENING RESULTS ON SOIL SAMPLES

<u>BORING NUMBER</u>	<u>SAMPLE NUMBER</u>	<u>SAMPLE DEPTH (feet)</u>	<u>LABORATORY PID READING</u>
GZ-7	S-1	0.8-2.8	0.7
	S-2	5-7	0.4
	S-3	10-12	---
	S-4	15-17	0.7
GZ-8	S-1	0.8-2.8	ND
	S-2	5-7	0.2
	S-3	10-12	---
	S-4	15-17	0.2
GZ-9	S-1	0.8-2.8	0.2
	S-2	5-7	---
	S-3	10-12	0.2
GZ-10	S-1	1-3	0.3
	S-2	5-7	---
	S-3	10-12	0.4
	S-4	12-14	0.4
GZ-11	S-1	0.8-2.8	1.1
	S-2	5-7	1.2
	S-3	10-12	---
	S-4	15-17	1.8
	S-5	20-22	0.8
	S-6	25-27	0.4
	S-7	32-34	0.4
	S-8	35-37	0.2
	S-9	40.5-42.5	0.2
	S-10	45-47	0.1
	S-11	50-52	0.3
	S-12	55-57	0.1
	S-13	58-60	0.2
	S-14	63-64.5	0.4

TABLE 14

SUMMARY OF DETECTED VOLATILE ORGANICS IN SEDIMENT
OF THE ABERJONA RIVER AT 60 OLYMPIA AVENUE

COMPOUND	UPSTREAM (ug/kg)		DOWNSTREAM (ug/kg)		SEDIMENT QUALITY CRITERIA (ug/kg)		HAZARD INDICES	
	GZA RS-1	EBASCO SD-02	GZA RS-2	EBASCO SD-03	CHRONIC	ACUTE	CHRONIC	ACUTE
<u>Aromatics:</u>								
Acetone	ND	(113.5)	430	(135.7)	13,700	95,900	3.1 E-02	4.5 E-03
2-Butanone	ND	(19.9)	ND	(11.7)				
Benzene	ND	(4.5)	ND	ND				
Methyl-t-butyl ether	ND	NT	100	NT		477,310		2.1 E-04
Methylene chloride	ND	(95.7)	ND	(85.5)				
Toluene	ND	(1.0)	ND	ND				
<u>Chlorinated:</u>								
1,1-Dichloroethane	ND	(3.8)	ND	ND				
Trichloroethane	ND	(1.1)	ND	ND				

Notes:

1. Data in parentheses are from Ebasco Services, Inc. river sediment sample stations SD-02 and SD-03, Endangerment Assessment for the Wells G and H Site, Woburn, Massachusetts, December 1988, EPA Contract Number 68-01-7250. GZA river sediment data reported in this table is from a September 1990 sampling round.
2. GZA and Ebasco Services river sediment sampling locations are shown on Figure 4.
3. Sediment Quality Criteria were calculated for acetone by multiplying the organic carbon partitioning coefficient (QSAR data base) by the fraction of organic carbon in the sediment estimated to be 1% and then by the LC50 for the great pond snail (QSAR database) for the acute SQC or an avoidance value for sunfish (QSAR data base) for the chronic SQC. The only toxicity information available for methyl-t-butyl was an LC50 for the fathead minnow. Therefore, an acute SQC was calculated following the procedure described above for acetone.
4. Hazard indices were calculated by dividing the concentration of a compound in GZA RS-2 by the SQC.
5. ND = Not detected.
6. NT = Not tested.

TABLE 15

**SUMMARY OF DETECTED SEMI-VOLATILE ORGANICS IN SEDIMENT
OF THE ABERJONA RIVER AT 60 OLYMPIA AVENUE**

COMPOUND	UPSTREAM	DOWNSTREAM	SEDIMENT QUALITY CRITERIA (ug/kg)	NOAA EFFECTS VALUES		Overall AET
	(ug/kg) EBASCO SD-02	(ug/kg) EBASCO SD-03		ER-L	ER-M	
Phthalates:						
Bis(2-ethylhexyl) phthalate	910.3	1,337.5	818,740	NA	NA	NA
Polynuclear aromatic:						
Acenaphthene	255.0	91.4	7,330	150	650	150
Anthracene	606.0	189.2	13,200	85	960	300
Benzo(a)anthracene	2,071.2	721.4	13,096	230	1600	550
Benzo(b)fluoranthene	1,963.4	960.7	17,345	NA	NA	NA
Benzo(k)fluoranthene	1,338.2	563.2	30,143	NA	NA	NA
Benzo(g,h,i)perylene	567.6	337.9	70,661	NA	NA	NA
Benzo(a)pyrene	1,649.9	673.0	10,630	400	2500	700
Chrysene	2,907.4	951.3	2,134	400	2800	900
Dibenz(a,h)anthracene	363.1	123.7	4,668	60	260	100
Fluoranthene	3,986.3	1,648.5	18,800	600	3600	1000
Indeno(1,2,3-cd)pyrene	649.1	373.1	177,493	NA	NA	NA
Napthalene	89.1	ND	8,760	340	2100	500
Phenanthrene	2,399.5	912.4	1,390	225	1380	260
Pyrene	3,737.5	1,366.9	13,100	350	2200	1000
TOTAL PAH	22,583.6	8,912.7	-	4000	35,000	22,000

Notes:

1. Data are from Ebasco Services, Inc. river sediment sample stations SD-02 and SD-03, Endangerment Assessment for the Wells G and H Site, Woburn, Massachusetts, December 1988, EPA Contract Number 68-01-7250.
2. Ebasco Services sediment sampling locations are shown on Figure 4.
3. ND = Not detected.
4. Sediment Quality Criteria were obtained by multiplying the AWQC or other toxicity value by the organic carbon partitioning coefficient and then by the fraction of organic carbon conservatively estimated to be 1%. For PAHs where no toxicity data were available, the value for benzo(a)pyrene is substituted to obtain a rough estimate of a sediment quality criteria.

TABLE 15 (continued)

5. The NOAA effects based sediment criteria are for marine sediment, however, in lieu of any equivalent data for freshwater sediment it is provided for comparison. Source: Long, E. R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. Seattle, Washington.

The ER-L values are concentrations equivalent to the lower 10 percentile of the screened available data, and indicate the low end of the range of concentrations in which effects on sensitive life stages or species were observed or predicted. The ER-M values are the concentrations equivalent to the 50 percentile point in the screened available data, and are used to document concentrations above which adverse effects were frequently or always observed or predicted among most species. The Overall Apparent Effects Threshold is the sediment concentration of a chemical above which statistically significant biological effects always occur.

TABLE 16

**SUMMARY OF DETECTED VOLATILE ORGANICS IN SOIL
OF THE ABERJONA RIVER WETLAND AT 60 OLYMPIA AVENUE**

COMPOUND	RED MAPLE SWAMP (ug/kg)	PARKING LOT OUTFALL (ug/kg)	SEDIMENT QUALITY CRITERIA (ug/kg)		HAZARD INDEX	
			Chronic	Acute	Chronic	Acute
VOLATILE ORGANICS	<u>GZA SS-1</u>	<u>GZA SS-2</u>				
<u>Aromatics:</u>						
Toluene	ND	5.3	2,145	96,250	2.5 E-03	5.5 E-05

Notes:

1. GZA wetland soil data reported in this table is from a September 1990 sampling round.
2. GZA wetland soil sampling locations are shown on Figure 4.
3. ND = Not detected.
4. Sediment Quality Criteria were obtained by multiplying the AWQC (for acute SQC) and lowest observed effect level on Leopard Frog larvae (for chronic SQC; values from QSAR data base) by the organic carbon partitioning coefficient for toluene (QSAR data base) and then by the fraction of organic carbon conservatively estimated to be 1%.
5. Hazard indices were calculated by dividing the concentration of toluene detected at GZA SS-2 by the sediment quality criteria.

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NOTES:

1. Dose-Response information obtained from the following:
 - a. U.S. EPA, Integrated Risk Information System (IRIS). Chemical Files. Dialcom/BT Tymnet Computer Communication Service. October, 1990.
 - b. U.S. EPA. Health Effects Assessment Summary Tables (HEAST). Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response. Third Quarter FY 1990, July, 1990.
 - c. Reference Doses for MTBE were based on the U.S. EPA recommended One Day Health Advisory, which was obtained from USEPA, Office of Water, Oct., 1989.
2. Weight of Evidence Classification:

Group A: Human Carcinogen
Group B-1: Probable Human Carcinogen; Limited evidence of carcinogenicity in humans from epidemiologic studies.
Group B-2: Probable Human Carcinogen; Sufficient evidence of carcinogenicity in animals, inadequate evidence in humans.
Group C: Possible Human Carcinogen
Group D: Not Classified
Group E: No Evidence of Human Carcinogenicity
3. Dose-response values are not available for direct contact exposure, therefore values for exposure through ingestion were used.
4. Xylenes include Ortho, Meta, and Para isomers of Xylene.
5. NA = Not Applicable or Not Available

TABLE 17 (continued)
SUMMARY OF DOSE-RESPONSE INFORMATION
FOR INHALATION EXPOSURE

4596.20
October 1990

COMPOUND	NONCARCINOGENIC EFFECTS			CARCINOGENIC EFFECTS	
	Subchronic Rfd (mg/kg/day)	Chronic Rfd (mg/kg/day)	TOXICITY ENDPOINT(S)	CPF (mg/kg/day)-1	CLASS
Volatile Organic Compounds (VOCs)					
Aromatics:					
Benzene	3E-03 c	3E-03 c	NA	2.9E-02 a	A
N-Butylbenzene	NA	NA	NA	NA	NA
Sec-Butylbenzene	NA	NA	NA	NA	NA
Tert-Butylbenzene	NA	NA	NA	NA	NA
Ethylbenzene	2E-01 c	2E-01 c	NA	NA	D
Isopropylbenzene	NA	NA	NA	NA	NA
P-Isopropyltoluene	NA	NA	NA	NA	NA
Napthalene	2E-02 c	2E-02 c	NA	NA	D
N-Propylbenzene	NA	NA	NA	NA	NA
Toluene	6E-01 b	6E-01 b	CNS Effects, eyes & nose irritation	NA	D
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	NA	NA
Xylenes	9E-02 b	9E-02 b	CNS Effects, nose & throat irritation	NA	D
Chlorinated VOCs:					
Chloroform	2E-01 c	2E-01 c	NA	8.1E-02 b	B-2
1,1-Dichloroethane	1E+00 b	1E-01 b	Kidney effects	NA	C
1,2-Dichloroethane	2E-02 c	2E-02 c	NA	9.1E-02 b	B-2
1,1-Dichloroethene	1E-03 c	1E-03 c	NA	1.2E+00 b	C
cis-1,2-Dichloroethene	3E-01 c	3E-01 c	NA	NA	D
trans-1,2-Dichloroethene	3E-01 c	3E-01 c	NA	NA	D
Tetrachloroethene	1E+00 c	1E+00 c	NA	3.3E-03 b	B-2
1,2,4-Trichlorobenzene	3E-02 b	3E-03 b	Liver, Kidney effects	NA	D
Trichloroethene	5E-02 c	5E-02 c	NA	1.7E-02 b	B-2
1,1,2-Trichloroethane	2E-02 c	2E-02 c	NA	NA	D
Vinyl Chloride	5E-03 c	5E-03 c	NA	3.0E-01	A
Total Petroleum Hydrocarbons	NA	NA	NA	NA	NA

NOTES:

1. Dose-Response information obtained from the following:

- a. U.S. EPA, Integrated Risk Information System (IRIS). Chemical Files. Dialcom/BT Tymnet Computer Communication Service. April, 1990.
- b. U.S. EPA. Health Effects Assessment Summary Tables (HEAST). Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response. Fourth Quarter FY 1989. 2nd Quarter, 1990.

Inhalation RfDs for toluene and xylene were calculated from the acceptable concentration (in mg/m³) using standard exposure assumptions:

$$\text{Rfd (mg/kg/day)} = \text{conc (mg/m}^3\text{)} \times 20 \text{ m}^3 \text{ air/day} \times 1/70 \text{ kg bodyweight}$$

- c. Massachusetts Department of Environmental Protection. Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan. Office of Research and Standards. May 17, 1989.

Inhalation acceptable doses (AD) were calculated from ATC's using standard exposure assumptions:

$$\text{AD in (mg/kg/day)} = \text{ATC (ug/m}^3\text{)} \times 20 \text{ m}^3 \text{ air/day} \times 1/70 \text{ kg bodyweight} \times 1 \text{ mg/1000 ug}$$

These values were used for chronic and subchronic effects.

2. Weight of Evidence Classification:

Group A: Human Carcinogen
Group B-1: Probable Human Carcinogen; Limited evidence of carcinogenicity in humans from epidemiologic studies.
Group B-2: Probable Human Carcinogen; Sufficient evidence of carcinogenicity in animals, inadequate evidence in humans.
Group C: Possible Human Carcinogen
Group D: Not Classified
Group E: No Evidence of Human Carcinogenicity

3. NA = Not Applicable or Not Available

TABLE 18

4596.20
July 1991DRINKING WATER STANDARDS & GUIDELINES
FOR COMPOUNDS DETECTED IN
GROUNDWATER

COMPOUND	MASSACHUSETTS DRINKING WATER STANDARDS		FEDERAL STANDARDS	
	STANDARDS MCLs (mg/l)	GUIDELINES (mg/l)	MCLs (mg/l)	MCLGs (mg/l)
VOLATILE ORGANICS (VOCs)				
Aromatics:				
Benzene	0.005	NA	0.005	0
Ethylbenzene	NA	0.7	0.7	0.7
Toluene	NA	2	1	1
Xylenes (total)	NA	1	10	10
N-Butylbenzene	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	NA
p-Isopropylbenzene	NA	NA	NA	NA
Naphthalene	NA	NA	NA	NA
m-Propylbenzene	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	NA
Chlorinated VOCs:				
Chloroform	0.100 **	0.005	0.100 **	0
1,1-Dichloroethane	NA	0.005	NA	NA
1,2-Dichloroethane	0.005	NA	0.005	0
1,1-Dichloroethene	0.007	NA	0.007	0.007
cis-1,2-Dichloroethene	NA	0.07	0.07	0.07
trans-1,2-Dichloroethene	NA	0.07	0.1	0.1
Tetrachloroethene	NA	0.005	0.005	0
1,2,4-Trichlorobenzene	NA	NA	0.009 *	0.009 *
Trichloroethene	0.005	NA	0.005	0
1,1,2-Trichloroethane	NA	0.003	0.005 *	0.003
Vinyl Chloride	0.002	NA	0.002	0
Total Petroleum Hydrocarbons	NA	NA	NA	NA

NOTES:

- Massachusetts Standards and Guidelines obtained from: Department of Environmental Protection, 1989. Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan. Office of Research and Standards. Update: October 1990.
- Federal Standards taken from: National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143. Values listed with an asterisk (*) are proposed standards, as listed in 55FR30370 (July 25, 1990).
- ** = MCL for total trihalomethanes, including chloroform.
- MCL - Maximum Contaminant Level
MCLG - Maximum Contaminant Level Goal
- NA = No Federal or Massachusetts standards or guidelines are available.

TABLE 19

EXPOSURE ASSESSMENT SUMMARY

<u>Receptor</u>	<u>Time Frame</u>	<u>Activity</u>	<u>Exposure Point</u>	<u>Medium</u>	<u>Route</u>
Adult Construction Worker	future	Excavation of site	Facility Grounds	Soil* Soil gas* (volatilization)	Dermal Contact Ingestion Inhalation
Adult and Child Residents	future	Consumption of drinking water, household use of water	Residences Supplied by Wells G&H	Groundwater	Ingestion Inhalation Dermal Contact
Adults and Child Residents	future	Incidental contact	Aberjona River	Surface Water	Dermal Contact Incidental Ingestion

Notes:

*Indicate media for which measured concentrations are available. For others, concentrations will be estimated using modeling techniques.

TABLE 20
EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
DIRECT CONTACT TO SOILS

4596.20
October 1990

VARIABLE	EXPOSURE ASSUMPTIONS AND REFERENCES	
	FUTURE USE	NOTES
GENERAL:		
Person	Adult Worker	
Age	18-65 years	1
Average Body Weight	70 kg	2
Duration of Exposure		
Years	1 year	3
Days	250 days/year	
Hours	4 hours/day	
Lifetime Averaging Factor for Carcinogenic Risk	1 year/ 70 years	4
DERMAL ABSORPTION:		
Absorption Factor VOCs	0.25	5
Total Skin Area	18000 cm ²	2
Fraction of Skin Covered	0.20	2
Amount of Soil on Skin	0.5 mg/cm ² -day	5
INCIDENTAL INGESTION:		
Absorption Factor	1	6
Amount of Soils Ingested	0.05 grams/day	5
CONCENTRATION OF OHM:	MEAN mg/kg	7

TABLE 20 (continued)
EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
DIRECT CONTACT TO SOILS

CALCULATION OF AVERAGE DAILY DOSES

Soils:

$$\text{mg/kg/day} = \text{concentration (mg/kg)} \times \text{chemical exposure factor (kg/kg/day)}$$

FUTURE USE: Adult Worker

SUBCHRONIC NONCARCINOGENIC EXPOSURE FACTORS:

$$\begin{aligned} \text{mg/kg/day} = & \text{concentration (mg/kg)} \times 1/\text{bodyweight (kg)} \times \text{days/year} \\ & \times 1 \text{ year}/365 \text{ days} \\ & \times \{(\text{skin area (cm}^2) \times \text{fraction covered} \\ & \times \text{soil on skin (mg/cm}^2\text{-day)} \times 1 \text{ kg}/1000000 \text{ mg} \\ & \times \text{absorption factor}) + (\text{soil ingested (gm/day)} \\ & \times 1 \text{ kg}/1000\text{gm} \times \text{ingestion absorption factor})\} \end{aligned}$$

$$\text{VOCs:} \quad \text{mg/kg/day} = \text{concentration (mg/kg)} \times 4.9\text{E-}06 \text{ kg/kg/day}$$

CARCINOGENIC EXPOSURE FACTORS:

$$\begin{aligned} \text{mg/kg/day} = & \text{concentration (mg/kg)} \times 1/\text{bodyweight (kg)} \times \text{days/year} \\ & \times 1 \text{ year}/365 \text{ days} \times \text{averaging factor (years/years)} \\ & \times \{(\text{skin area (cm}^2) \times \text{fraction covered} \\ & \times \text{soil on skin (mg/cm}^2\text{-day)} \times 1 \text{ kg}/1000000 \text{ mg} \\ & \times \text{absorption factor}) + (\text{soil ingested (gm/day)} \\ & \times 1 \text{ kg}/1000\text{gm} \times \text{ingestion absorption factor})\} \end{aligned}$$

$$\text{VOCs:} \quad \text{mg/kg/day} = \text{concentration (mg/kg)} \times 7.0\text{E-}08 \text{ kg/kg/day}$$

TABLE 20 (continued)

EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
DIRECT CONTACT TO SOILS

NOTES:

1. Adults, 18-65 years of age, were used to represent the potential occupational receptor population.
2. Average body weight, total skin area, and fraction of skin area of the receptor populations based on: Exposure Factors Handbook, USEPA, Office of Health and Environmental Assessment, Washington, D.C., EPA 600/8-89/043. July 1989.
3. The duration of exposure was conservatively based on the nature of excavation activities, including building demolition, reparations, or total site excavation, which may occur at the study site.
4. The lifetime averaging factor for carcinogenic risk was based on 1 year of exposure over a 70 year lifetime.
5. Dermal absorption factors, amount of soil covering skin and ingested, were obtained from: "Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan." Massachusetts Department of Environmental Protection, Office of Research and Standards, May 17, 1989.
6. The absorption factor for ingestion was assumed to be 100%, and was obtained from: "Draft Final Supplemental Guidance for the Superfund Program." Part I - Guidance for Public Health Risk Assessment. USEPA Region I, Boston, MA. EPA 901/5-89-001. June 1989.
7. Arithmetic mean concentrations of the OHM detected in unsaturated zone boring soils in the area of contamination were calculated to represent exposure point concentrations.

TABLE 21
 CALCULATION OF CHEMICAL EXPOSURE FACTORS
 INHALATION OF SOIL GAS

4596.2
 August 1990

VARIABLE	EXPOSURE ASSUMPTIONS AND REFERENCES	
	CURRENT USE	NOTES
GENERAL:		
Person	Adult Worker	
Age	18-65 years	1
Average Body Weight	70 kg	2
Duration of Exposure		
Years	1 year	3
Days	250 days/year	
Hours	4 hours/day	
Lifetime Averaging Factor for Carcinogenic Risk	1 year/ 70 years	4
INHALATION:		
Absorption Factor	1.0	5
Air Inhaled per hour	2.1 m ³	6
CONCENTRATION OF OHM:	MEAN mg/m ³	7

TABLE 21 (continued)

CALCULATION OF CHEMICAL EXPOSURE FACTORS
INHALATION OF SOIL GAS

CURRENT USE: Adult Worker

NONCARCINOGENIC SUBCHRONIC EXPOSURE FACTOR:

$\text{mg/kg/day} = \text{concentration (mg/m}^3\text{)} \times 1/\text{bodyweight (kg)}$
 $\times \text{hours/day} \times \text{days/year} \times 1 \text{ year}/365 \text{ days}$
 $\times \text{air inhaled (m}^3\text{/hour)} \times \text{absorption factor}$

$\text{mg/kg/day} = \text{concentration (mg/m}^3\text{)} \times 8.2\text{E-}02 \text{ m}^3\text{/kg/day}$

CARCINOGENIC EXPOSURE FACTOR:

$\text{mg/kg/day} = \text{concentration (mg/m}^3\text{)} \times 1/\text{bodyweight (kg)} \times \text{hours/day}$
 $\times \text{days/year} \times 1 \text{ year}/365 \text{ days} \times \text{avg factor (years/years)}$
 $\times \text{air inhaled (m}^3\text{/hour)} \times \text{absorption factor}$

$\text{mg/kg/day} = \text{concentration (mg/m}^3\text{)} \times 1.2\text{E-}03 \text{ m}^3\text{/kg/day}$

TABLE 21 (continued)

CALCULATION OF CHEMICAL EXPOSURE FACTORS
INHALATION OF SOIL GAS

NOTES:

1. Adults, 18-65 years of age, were used to represent the potential occupational receptor population.
2. Average body weight of the receptor populations based on: "Exposure Factors Handbook," USEPA, Office of Health and Environmental Assessment, Washington D.C., EPA 600/8-89/043. July 1989.
3. The duration of exposure was conservatively based on the nature of excavation activities which may occur at the site.
4. The lifetime averaging factor for carcinogenic risk was based on 1 year of exposure over a 70 year lifetime.
5. Absorption assumed to be 100 percent.
6. The amount of air inhaled per hour during moderate activity obtained from: Exposure Factors Handbook, USEPA, Office of Health and Environmental Assessment, Exposure Assessment Group. Washington D.C., EPA 600/8-89/043. July 1989. Table 3-1.
7. Arithmetic Mean concentrations of the OHM detected in soil gas were divided by 100 to account for the effects of dispersion. The resultant air concentrations were used to represent exposure point concentrations.

TABLE 22

4596.20
October 1990CALCULATION OF CHEMICAL EXPOSURE FACTORS
FOR EXPOSURES TO GROUNDWATER
VIA INGESTION, DIRECT CONTACT AND INHALATION

VARIABLE	EXPOSURE ASSUMPTIONS AND REFERENCES		
	FUTURE USE	FUTURE USE	NOTES
GENERAL:			
Person	Adult Resident	Child Resident	1
Age	18-70 years	2-3 years	1
Average Body Weight	70 kg	13.1 kg	2
Duration of Exposure			
Years	70 years	1 year	3
Days	365 days/year	365 days/year	
Lifetime Averaging Factor for Carcinogenic Risk	70 years/ 70 years	NA NA	4
INGESTION:			
Average Amount of Water Ingested	2 liters/day	1 liter/day	5
INHALATION, DIRECT CONTACT:			
VOCs: 3 X Ingestion Exposure Factor			5
Absorption Factor	1		
CONCENTRATION OF OHM:	MEAN mg/l	MEAN mg/l	6

TABLE 22 (continued)

EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
FOR EXPOSURES TO GROUNDWATER

FUTURE USE: Child Resident

NONCARCINOGENIC CHRONIC EXPOSURE FACTORS:

$\text{mg/kg/day} = \text{concentration (mg/l)} \times 1/\text{bodyweight (kg)} \times \text{days/year}$
 $\times 1 \text{ year}/365 \text{ days} \times \text{amount ingested (l/day)} \times \text{AF}$

VOCs: $\text{mg/kg/day} = \text{concentrtn. (mg/l)} \times 3 \times 7.6\text{E-}02 \text{ l/kg/day}$

FUTURE USE: Adult Resident

CARCINOGENIC EXPOSURE FACTORS:

$\text{mg/kg/day} = \text{concentration (mg/l)} \times 1/\text{bodyweight (kg)} \times \text{days/year}$
 $\times 1 \text{ year}/365 \text{ days} \times \text{averaging factor (years/years)}$
 $\times \text{amount ingested (l/day)} \times \text{absorption factor (AF)}$

VOCs: $\text{mg/kg/day} = \text{concentrtn. (mg/l)} \times 3 \times 2.9\text{E-}02 \text{ l/kg/day}$

TABLE 22 (continued)
EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
FOR EXPOSURES TO GROUNDWATER

NOTES:

1. Adults, 18-70 years of age, and children, ages 2-3 years, were used to represent the potential residential receptor population.
2. Average body weight of the receptor population based on: Anderson, E., et al. Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessment. U.S. EPA Office of Health and Environmental Assessment, Washington, D.C., EPA 600/8-85/010. August 1985. Tables 2-1 and 2-2 (adults) and 2-3, 2-4 (children).
3. The duration of exposure was conservatively based on the nature of potential future use of site groundwater as a water supply.
4. The lifetime averaging factor for carcinogenic risk was based on 70 year of exposure over a 70 year lifetime.
5. Drinking water ingestion rates and rationale for multiplying ingestion exposure factor by 3 to account for ingestion, direct contact and inhalation, were obtained from "Guidance for Disposal Site Risk characterization and Related Phase II Activities-In Support of the MCP." Mass. Department of Environmental Protection, Office of Research and Standards, May 17, 1989.
6. Mean detected concentrations of OHM detected in groundwater were assumed to represent exposure point concentrations.

TABLE 23

4596.20
October 1990CALCULATION OF CHEMICAL EXPOSURE FACTORS
DIRECT CONTACT TO SURFACE WATER

VARIABLE	EXPOSURE ASSUMPTIONS AND REFERENCES		
	FUTURE USE	FUTURE USE	NOTES
GENERAL:			
Person	Adult Resident	Child Resident	
Age	18-70 years	2-3 years	1
Average Body Weight	70 kg	13.1 kg	2
Duration of Exposure			
Years	1	1 year	3
Days	90 days/year	90 days/year	
Hours	2 hours/day	2 hours/day	
Lifetime Averaging Factor for Carcinogenic Risk	52 years/ 70 years	NA NA	4
DERMAL ABSORPTION:			
Absorption Factor	1	1	2
Total Skin Area	18000 cm2	5910 cm2	2
Fraction Exposed	1	1	
Skin Permeability Rate	0.001 l/cm2-hour	0.001 l/cm2-hour	2
INCIDENTAL INGESTION:			
Absorption Factor	1	1	5
Amount of Water Ingested	50 ml/swim	50 ml/swim	2
CONCENTRATION OF OHM:	MEAN mg/l	MEAN mg/l	6

TABLE 23 (continued)

EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
FOR EXPOSURES TO SURFACE WATER

FUTURE USE: Child Resident

NONCARCINOGENIC CHRONIC EXPOSURE FACTORS:

mg/kg/day = concentration (mg/l) x 1/bodyweight (kg) x days/days
x ((hours/days x skin area (cm²) x fraction exposed
x permeability rate (l/cm²-hr) x absorption factor)
+ (water ingested (ml)/swim x 1/1000 ml))

mg/kg/day = concntrtn. (mg/l) x 2.2E-01 l/kg/day

FUTURE USE: Adult Resident

CARCINOGENIC EXPOSURE FACTORS:

mg/kg/day = concentration (mg/l) x 1/bodyweight (kg) x days/days
x [(hours/days x skin area (cm²) x fraction exposed
x permeability rate (l/cm²-hr) x absorption factor)
+ (water ingested/swim (ml) x 1/1000 ml)]
x averaging factor (years/years)

mg/kg/day = concntrtn. (mg/l) x 9.4E-02 l/kg/day

TABLE 23 (continued)
EQUATIONS FOR CHEMICAL EXPOSURE FACTORS
FOR EXPOSURES TO SURFACE WATER

NOTES:

1. Adults, 18-70 years of age, and children, ages 2-3 years, were used to represent the potential residential receptor population.
2. Average body weight, skin area, permeability constant, absorption factor, and amount ingested/swim, of the receptor populations based on: "Exposure Factors Handbook," USEPA, Office of Health and Environmental Assessment, Washington, D.C., EPA 600/8-89/043. July 1989.
3. The duration of exposure was conservatively based on the nature of the current and potential future use of the Aberjona River for recreational purposes, such as swimming.
4. The lifetime averaging factor for carcinogenic risk was based on 52 years of exposure over a 70 year lifetime.
5. The incidental ingestion absorption factor was obtained from: "Draft Final Supplemental Guidance for the Superfund Program," Part I - Guidance for Public Health Risk Assessment. USEPA Region I, Boston, MA. EPA 901/5-89-001. June 1989.
6. Modelled concentrations of OHM in surface water were used to represent exposure point concentrations.

TABLE 24

COMPARISON OF GROUNDWATER CONCENTRATIONS TO
DRINKING WATER STANDARDS & GUIDELINES
FOR COMPOUNDS DETECTED IN
GROUNDWATER

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COMPOUND	MEAN SITE GROUNDWATER CONCENTRATIONS (mg/l)	MASS. GROUNDWATER STANDARDS (mg/l)	PREDICTED WELLS G & H CONCENTRATIONS (mg/l)	MASSACHUSETTS STANDARDS MMCLs (mg/l)	DRINKING WATER GUIDELINES (mg/l)	FEDERAL MCLs (mg/l)	STANDARDS MCLGs (mg/l)
VOLATILE ORGANICS (VOCs)							
Aromatics:							
Benzene	3.7E-03 (5)	0.005	3.2E-05	0.005	NA	0.005	0
Ethylbenzene	5.2E-04	0.7	3.1E-06	NA	0.7	0.7	0.7
Toluene	1.6E-03	2	1.1E-05	NA	2	1	1
Xylenes (total)	1.7E-03	1	1.1E-05	NA	1	10	10
N-Butylbenzene	2.7E-02	NA	2.9E-06	NA	NA	NA	NA
sec-Butylbenzene	4.4E-04	NA	2.8E-06	NA	NA	NA	NA
tert-Butylbenzene	4.6E-04	NA	2.8E-06	NA	NA	NA	NA
Isopropylbenzene	5.5E-04	NA	3.3E-06	NA	NA	NA	NA
P-Isopropyltoluene	4.5E-04	NA	2.6E-06	NA	NA	NA	NA
Naphthalene	7.3E-04	NA	4.4E-06	NA	NA	NA	NA
N-Propylbenzene	5.4E-04	NA	3.2E-06	NA	NA	NA	NA
1,2,4-Trimethylbenzene	5.9E-04	NA	3.5E-06	NA	NA	NA	NA
1,3,5-Trimethylbenzene	6.1E-04	NA	3.7E-06	NA	NA	NA	NA
Chlorinated:							
Chloroform	5.8E-04	NA	3.5E-06	0.100 **	0.005	0.100 **	0
1,1-Dichloroethane	5.7E-04	NA	3.4E-06	NA	0.005	NA	NA
1,2-Dichloroethane	4.4E-04	0.005	2.6E-06	0.005	NA	0.005	0
1,1-Dichloroethene	5.0E-04	0.007	2.9E-06	0.007	NA	0.007	0.007
cis-1,2-Dichloroethene	2.9E-03	NA	1.7E-05	NA	0.07	0.07	0.07
trans-1,2-Dichloroethene	5.5E-04	NA	3.3E-06	NA	0.07	0.1	0.1
Tetrachloroethene	3.3E-03	0.005	1.0E-05	NA	0.005	0.005	0
1,2,4-Trichlorobenzene	5.0E-04	NA	2.9E-06	NA	NA	0.009 *	0.009 *
Trichloroethene	1.1E-03	0.005	6.8E-06	0.005	NA	0.005	0
1,1,2-Trichloroethane	4.7E-04	NA	2.8E-06	NA	0.003	0.005 *	0.003 *
Vinyl Chloride	4.8E-04	0.002	2.9E-06	0.002	NA	0.002	0
Total Petroleum Hydrocarbons	1.1E+00	NA	1.4E-02	NA	NA	NA	NA

TABLE 24
COMPARISON OF GROUNDWATER CONCENTRATIONS TO
DRINKING WATER STANDARDS & GUIDELINES
FOR COMPOUNDS DETECTED IN
GROUNDWATER

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NOTES:

1. Massachusetts Standards and Guidelines obtained from: Department of Environmental Protection, 1989. Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan. Office of Research and Standards. Update: October 1990.
2. Federal Standards taken from: National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143. Values listed with an asterisk (*) are proposed standards, as listed in 55FR30370 (July 25, 1990).
3. ** = MCL for total trihalomethanes, including chloroform.
4. MCL - Maximum Contaminant Level
MCLG - Maximum Contaminant Level Goal
5. NA = No Federal or Massachusetts standards or guidelines are available.
6. The mean site groundwater concentration for Benzene exceeds the applicable standard or guideline.

TABLE 25

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
DIRECT CONTACT TO SOILS

FUTURE USE: Adult Worker
SUBCHRONIC NONCARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/kg)	CHEMICAL EXPOSURE FACTOR (kg/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	REFERENCE DOSE (mg/kg/day)	HAZARD INDEX
VOLATILE ORGANICS					
Aromatics:					
Benzene	6.0E-03	4.9E-06	2.9E-08	NA	NA
Ethylbenzene	2.7E-02	4.9E-06	1.3E-07	1E+00	1.3E-07
Toluene	1.8E-02	4.9E-06	8.8E-08	4E-01	2.2E-07
M,P-Xylenes	1.4E-02	4.9E-06	6.9E-08	4E+00	1.7E-08
O-Xylene	1.5E-02	4.9E-06	7.4E-08	4E+00	1.8E-08
Chlorinated:					
total-1,2-Dichloro- ethenes	3.8E-03	4.9E-06	1.9E-08	2E-01	9.3E-08
Tetrachloroethene	3.4E-03	4.9E-06	1.7E-08	1E-01	1.7E-07
Trichloroethene	1.3E-02	4.9E-06	6.4E-08	NA	NA
Other:					
Methyl-t-Butyl Ether	9.4E-01	4.9E-06	4.6E-06	7E-02	6.6E-05
Subtotal:					6.6E-05

TABLE 25 (continued)

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
DIRECT CONTACT TO SOILSFUTURE USE: Adult Worker
CARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/kg)	CHEMICAL EXPOSURE FACTOR (kg/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	CARCINOGENIC POTENCY FACTOR (mg/kg/day) ⁻¹	INCREMENTAL CANCER RISK ESTIMATE
VOLATILE ORGANICS					
Aromatics:					
Benzene	6.0E-03	7.0E-08	4.2E-10	2.9E-02	1.2E-11
Ethylbenzene	2.7E-02	7.0E-08	1.9E-09	NA	NA
Toluene	1.8E-02	7.0E-08	1.3E-09	NA	NA
M,P-Xylenes	1.4E-02	7.0E-08	9.8E-10	NA	NA
O-Xylene	1.5E-02	7.0E-08	1.1E-09	NA	NA
Chlorinated:					
total-1,2-Dichloro-ethenes	3.8E-03	7.0E-08	2.7E-10	NA	NA
Tetrachloroethene	3.4E-03	7.0E-08	2.4E-10	5.1E-02	1.2E-11
Trichloroethene	1.3E-02	7.0E-08	9.1E-10	1.1E-02	1.0E-11
Other:					
Methyl-t-Butyl Ether	9.4E-01	7.0E-08	6.6E-08	NA	NA
Subtotal:					3.4E-11

TABLE 26

4596.2
Jan. 1991CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
SOIL GAS INHALATIONCURRENT USE: Adult Worker
SUBCHRONIC NONCARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/m ³)	CHEMICAL EXPOSURE FACTOR (m ³ /kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	REFERENCE DOSE (mg/kg/day)	HAZARD INDEX
VOCs					
Aromatics:					
Benzene	2.8E-03	8.2E-02	2.3E-04	3.0E-03	7.7E-02
Toluene	3.5E-03	8.2E-02	2.9E-04	6.0E-01	4.8E-04
M,P-Xylenes	3.9E-03	8.2E-02	3.2E-04	9.0E-02	3.6E-03
O-Xylenes	2.9E-03	8.2E-02	2.4E-04	9.0E-02	2.6E-03
Chlorinated:					
Tetrachloroethene	4.8E-02	8.2E-02	3.9E-03	1.0E+00	3.9E-03
Trichloroethene	2.6E-02	8.2E-02	2.1E-03	5.0E-02	4.2E-02
Subtotal:					1.3E-01

TABLE 26 (continued)

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
SOIL GAS INHALATIONCURRENT USE: Adult Worker
CARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/m ³)	CHEMICAL EXPOSURE FACTOR (m ³ /kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	CARCINOGENIC POTENCY FACTOR (mg/kg/day) ⁻¹	INCREMENTAL CANCER RISK ESTIMATE
VOCs					
Aromatics:					
Benzene	2.8E-03	1.2E-03	3.4E-06	2.9E-02	9.7E-08
Toluene	3.5E-03	1.2E-03	4.2E-06	NA	NA
M,P-Xylenes	3.9E-03	1.2E-03	4.7E-06	NA	NA
O-Xylenes	2.9E-03	1.2E-03	3.5E-06	NA	NA
Chlorinated:					
Tetrachloroethene	4.8E-02	1.2E-03	5.8E-05	3.3E-03	1.9E-07
Trichloroethene	2.6E-02	1.2E-03	3.1E-05	1.7E-02	5.3E-07
Subtotal:					8.2E-07

NOTES:

1. Average soil gas concentrations from Table 4 were converted to mg/m³ using the following equation:

$$[\text{mg/m}^3] = [\text{ppm}] / (22.414 / \text{molecular weight})$$
2. Exposure point concentrations were estimated using the average soil soil gas concentration (mg/m³) and a dispersion factor of 100.

TABLE 27

File No. 4596.2
March 1991CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
EXPOSURES TO GROUNDWATERFUTURE USE: Residents
SUBCHRONIC NONCARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC.(1) (mg/l)	CHEMICAL EXPOSURE FACTOR (l/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	REFERENCE DOSE (mg/kg/day)	HAZARD INDEX
VOCs					
Aromatics:					
Benzene	2.2E-05	2.3E-01	5.0E-06	NA	NA
N-Butylbenzene	1.6E-04	2.3E-01	3.7E-05	NA	NA
Sec-butylbenzene	2.8E-06	2.3E-01	6.3E-07	NA	NA
Tert-Butylbenzene	2.8E-06	2.3E-01	6.3E-07	NA	NA
Ethylbenzene	3.1E-06	2.3E-01	7.1E-07	1.0E+00	7.1E-07
Isopropylbenzene	3.3E-06	2.3E-01	7.5E-07	NA	NA
P-Isopropylbenzene	2.6E-06	2.3E-01	6.0E-07	NA	NA
Naphthalene	4.4E-06	2.3E-01	1.0E-06	4.0E-03	2.5E-04
N-Propylbenzene	3.2E-06	2.3E-01	7.4E-07	NA	NA
Toluene	9.5E-06	2.3E-01	2.2E-06	4.0E-01	5.4E-06
1,2,4-Trimethylbenzene	3.5E-06	2.3E-01	8.1E-07	NA	NA
1,3,5-Trimethylbenzene	3.7E-06	2.3E-01	8.3E-07	NA	NA
O-Xylenes	4.9E-06	2.3E-01	1.1E-06	4.0E+00	2.8E-07
P,M-Xylenes	5.2E-06	2.3E-01	1.2E-06	4.0E+00	3.0E-07
Chlorinated:					
Chloroform	3.5E-06	2.3E-01	7.9E-07	1.0E-02	7.9E-05
1,1,-Dichloroethane	3.4E-06	2.3E-01	7.8E-07	1.0E+00	7.8E-07
1,2-Dichloroethane	2.6E-06	2.3E-01	6.0E-07	NA	NA
1,1-Dichloroethene	2.9E-06	2.3E-01	6.7E-07	9.0E-03	7.5E-05
cis-1,2-Dichloroethene	1.7E-05	2.3E-01	3.9E-06	NA	NA
trans-1,2-Dichloroethene	3.3E-06	2.3E-01	7.5E-07	2.0E-01	3.8E-06
Tetrachloroethne	2.0E-05	2.3E-01	4.5E-06	1.0E-01	4.5E-05
1,2,4-Trichlorobenzene	2.9E-06	2.3E-01	6.7E-07	2.0E-01	3.4E-06
Trichloroethene	6.8E-06	2.3E-01	1.6E-06	NA	NA
1,1,2-Trichloroethane	2.8E-06	2.3E-01	6.4E-07	4.0E-02	1.6E-05
Vinyl Chloride	2.9E-06	2.3E-01	6.6E-07	NA	NA
Subtotal:					4.8E-04

NOTE:

- The exposure point concentrations were estimated using the compound specific geometric means (Table 2), and the derived dilution factor of 167.

TABLE 27 (continued)

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
EXPOSURES TO GROUNDWATERFUTURE USE: Residents
CARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/l)	CHEMICAL EXPOSURE FACTOR (l/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	CARCINOGENIC POTENCY FACTOR (mg/kg/day) ⁻¹	INCREMENTAL CANCER RISK ESTIMATE
VOCs					
Benzene	2.2E-05	8.7E-02	1.9E-06	2.9E-02	5.5E-08
N-Butylbenzene	1.6E-04	8.7E-02	1.4E-05	NA	NA
Sec-butylbenzene	2.8E-06	8.7E-02	2.4E-07	NA	NA
Tert-Butylbenzene	2.8E-06	8.7E-02	2.4E-07	NA	NA
Ethylbenzene	3.1E-06	8.7E-02	2.7E-07	NA	NA
Isopropylbenzene	3.3E-06	8.7E-02	2.9E-07	NA	NA
P-Isopropylbenzene	2.6E-06	8.7E-02	2.3E-07	NA	NA
Naphthalene	4.4E-06	8.7E-02	3.8E-07	NA	NA
N-Propylbenzene	3.2E-06	8.7E-02	2.8E-07	NA	NA
Toluene	9.5E-06	8.7E-02	8.3E-07	NA	NA
1,2,4-Trimethylbenzene	3.5E-06	8.7E-02	3.1E-07	NA	NA
1,3,5-Trimethylbenzene	3.7E-06	8.7E-02	3.2E-07	NA	NA
O-Xylenes	4.9E-06	8.7E-02	4.3E-07	NA	NA
P,M-Xylenes	5.2E-06	8.7E-02	4.5E-07	NA	NA
Chlorinated:					
Chloroform	3.5E-06	8.7E-02	3.0E-07	6.1E-03	1.8E-09
1,1,-Dichloroethane	3.4E-06	8.7E-02	3.0E-07	9.1E-02	2.7E-08
1,2-Dichloroethane	2.6E-06	8.7E-02	2.3E-07	9.1E-02	2.1E-08
1,1-Dichloroethene	2.9E-06	8.7E-02	2.6E-07	6.1E-01	1.6E-07
cis-1,2-Dichloroethene	1.7E-05	8.7E-02	1.5E-06	NA	NA
trans-1,2-Dichloroethene	3.3E-06	8.7E-02	2.9E-07	NA	NA
Tetrachloroethne	2.0E-05	8.7E-02	1.7E-06	5.1E-02	8.8E-08
1,2,4-Trichlorobenzene	2.9E-06	8.7E-02	2.6E-07	NA	NA
Trichloroethene	6.8E-06	8.7E-02	6.0E-07	1.1E-02	6.5E-09
1,1,2-Trichloroethane	2.8E-06	8.7E-02	2.5E-07	NA	NA
Vinyl Chloride	2.9E-06	8.7E-02	2.5E-07	2.3E+00	5.8E-07
Subtotal:					9.3E-07

TABLE 28

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
EXPOSURES TO SURFACE WATER

FUTURE USE: Residents
SUBCHRONIC NONCARCINOGENIC EFFECTS

COMPOUND	PROJECTED EXPOSURE POINT CONC. (1) (mg/l)	CHEMICAL EXPOSURE FACTOR (l/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	REFERENCE DOSE (mg/kg/day)	HAZARD INDEX
VOCs					
Aromatics:					
Benzene	2.2E-05	2.5E-02	5.4E-07	NA	NA
N-Butylbenzene	2.0E-06	2.5E-02	4.9E-08	NA	NA
Sec-butylbenzene	1.8E-06	2.5E-02	4.6E-08	NA	NA
Tert-Butylbenzene	1.8E-06	2.5E-02	4.6E-08	NA	NA
Ethylbenzene	2.1E-06	2.5E-02	5.2E-08	1.0E+00	5.2E-08
Isopropylbenzene	2.2E-06	2.5E-02	5.5E-08	NA	NA
P-Isopropylbenzene	1.8E-06	2.5E-02	4.4E-08	NA	NA
Naphthalene	2.9E-06	2.5E-02	7.3E-08	4.0E-03	1.8E-05
N-Propylbenzene	2.2E-06	2.5E-02	5.4E-08	NA	NA
Toluene	7.1E-06	2.5E-02	1.8E-07	4.0E-01	4.4E-07
1,2,4-Trimethylbenzene	2.4E-06	2.5E-02	5.9E-08	NA	NA
1,3,5-Trimethylbenzene	2.4E-06	2.5E-02	6.1E-08	NA	NA
O-Xylenes	3.3E-06	2.5E-02	8.2E-08	4.0E+00	2.1E-08
P,M-Xylenes	3.5E-06	2.5E-02	8.7E-08	4.0E+00	2.2E-08
Chlorinated:					
Chloroform	2.3E-06	2.5E-02	5.8E-08	1.0E-02	5.8E-06
1,1-Dichloroethane	2.3E-06	2.5E-02	5.7E-08	1.0E+00	5.7E-08
1,2-Dichloroethane	1.8E-06	2.5E-02	4.4E-08	NA	NA
1,1-Dichloroethene	2.0E-06	2.5E-02	4.9E-08	9.0E-03	5.4E-06
cis-1,2-Dichloroethene	1.1E-05	2.5E-02	2.9E-07	NA	NA
trans-1,2-Dichloroethene	2.2E-06	2.5E-02	5.5E-08	2.0E-01	2.8E-07
Tetrachloroethne	6.6E-06	2.5E-02	1.7E-07	1.0E-01	1.7E-06
1,2,4-Trichlorobenzene	2.0E-06	2.5E-02	4.9E-08	2.0E-01	2.5E-07
Trichloroethene	4.6E-06	2.5E-02	1.1E-07	NA	NA
1,1,2-Trichloroethane	1.9E-06	2.5E-02	4.7E-08	4.0E-02	1.2E-06
Vinyl Chloride	1.9E-06	2.5E-02	4.8E-08	NA	NA
Subtotal:					3.3E-05

NOTE:

- The exposure point concentrations were estimated using the compound specific geometric means (Table 2), and the derived dilution factor of 250.

TABLE 28 (continued)

CALCULATION OF AVERAGE DAILY DOSES AND RISK ESTIMATES
EXPOSURES TO SURFACE WATERFUTURE USE: Residents
CARCINOGENIC EFFECTS

COMPOUND	EXPOSURE POINT CONC. (mg/l)	CHEMICAL EXPOSURE FACTOR (l/kg/day)	AVERAGE DAILY DOSE (mg/kg/day)	CARCINOGENIC POTENCY FACTOR (mg/kg/day) ⁻¹	INCREMENTAL CANCER RISK ESTIMATE
VOCs					
Benzene	2.2E-05	6.0E-03	1.3E-07	2.9E-02	3.8E-09
N-Butylbenzene	2.0E-06	6.0E-03	1.2E-08	NA	NA
Sec-butylbenzene	1.8E-06	6.0E-03	1.1E-08	NA	NA
Tert-Butylbenzene	1.8E-06	6.0E-03	1.1E-08	NA	NA
Ethylbenzene	2.1E-06	6.0E-03	1.2E-08	NA	NA
Isopropylbenzene	2.2E-06	6.0E-03	1.3E-08	NA	NA
P-Isopropylbenzene	1.8E-06	6.0E-03	1.1E-08	NA	NA
Naphthalene	2.9E-06	6.0E-03	1.8E-08	NA	NA
N-Propylbenzene	2.2E-06	6.0E-03	1.3E-08	NA	NA
Toluene	7.1E-06	6.0E-03	4.2E-08	NA	NA
1,2,4-Trimethylbenzene	2.4E-06	6.0E-03	1.4E-08	NA	NA
1,3,5-Trimethylbenzene	2.4E-06	6.0E-03	1.5E-08	NA	NA
O-Xylenes	3.3E-06	6.0E-03	2.0E-08	NA	NA
P,M-Xylenes	3.5E-06	6.0E-03	2.1E-08	NA	NA
Chlorinated:					
Chloroform	2.3E-06	6.0E-03	1.4E-08	6.1E-03	8.5E-11
1,1-Dichloroethane	2.3E-06	6.0E-03	1.4E-08	9.1E-02	1.2E-09
1,2-Dichloroethane	1.8E-06	6.0E-03	1.1E-08	9.1E-02	9.6E-10
1,1-Dichloroethene	2.0E-06	6.0E-03	1.2E-08	6.1E-01	7.2E-09
cis-1,2-Dichloroethene	1.1E-05	6.0E-03	6.9E-08	NA	NA
trans-1,2-Dichloroethene	2.2E-06	6.0E-03	1.3E-08	NA	NA
Tetrachloroethne	6.6E-06	6.0E-03	4.0E-08	5.1E-02	2.0E-09
1,2,4-Trichlorobenzene	2.0E-06	6.0E-03	1.2E-08	NA	NA
Trichloroethene	4.6E-06	6.0E-03	2.7E-08	1.1E-02	3.0E-10
1,1,2-Trichloroethane	1.9E-06	6.0E-03	1.1E-08	NA	NA
Vinyl Chloride	1.9E-06	6.0E-03	1.2E-08	2.3E+00	2.6E-08
Subtotal:					4.2E-08

TABLE 29
SUMMARY OF TOTAL HAZARD INDICES AND RISKS

ON- PROPERTY RECEPTORS	SOURCE AREA EXPOSURE MEDIUM/ROUTE	NONCARCINOGENIC HAZARD INDEX SUBCHRONIC	CARCINOGENIC RISK
Construction Workers	Former tank storage and pump areas		
	Direct Contact to Soils	6.6E-05	3.4E-11
	Former tank storage and pump areas		
	Inhalation of (Soil Gas) Volatiles	1.3E-01	8.2E-07
	TOTAL:	1.3E-01	8.2E-07
Residents	Wells G & H		
	Ingestion of Groundwater	4.8E-04	9.3E-07
	Direct Contact to Groundwater		
	Inhalation of Volatiles		
	Aberjona River		
	Direct Contact to Surface Water	3.3E-05	4.2E-08
	Incidental Ingestion of Surface Water		
	TOTAL:	5.1E-04	9.7E-07

NOTE:

1. The noncarcinogenic endpoints for the compounds detected in the areas are different, therefore the cumulative hazard index may be overestimates of potential effects.

TABLE 30

**PLANT SPECIES LIST FOR THE UNDEVELOPED LAND
IMMEDIATELY SURROUNDING THE 60 OLYMPIA AVENUE TRUCKING TERMINAL**

<u>Common Name</u>	<u>Latin Name</u>	<u>Fish and Wildlife Service Wetland Indicator Status</u>
<u>Mosses</u>		
Sphagnum Moss	<u>Sphagnum</u> sp.	OBL
<u>Ferns</u>		
Bracken Fern	<u>Pteridium aquilinum</u>	FACU
Cinnamon Fern	<u>Osmunda cinnamomea</u>	FACW
Marsh Fern	<u>Thelypteris thelypteroides</u>	FACW+
Royal Fern	<u>Osmunda regalis</u>	OBL
Sensitive Fern	<u>Onoclea sensibilis</u>	FACW
<u>Herbs</u>		
Bedstraw	<u>Galium</u> sp.	
Bog Hemp	<u>Boehmeria cylindrica</u>	FACW+
Broad-leaved Cattail	<u>Typha latifolia</u>	OBL
Deadly Nightshade	<u>Solanum dulcamara</u>	FAC-
Dodder	<u>Cuscuta</u> sp.	
Duckweed	<u>Lemna</u> sp.	OBL
Duck Potato	<u>Sagittaria latifolia</u>	OBL
Goldenrod	<u>Solidago</u> sp.	
Marsh St. John's-wort	<u>Triadenum virginicum</u>	OBL
Purple Loosestrife	<u>Lythrum salicaria</u>	FACW+
Reed	<u>Phragmites australis</u>	FACW
Rice Cutgrass	<u>Leersia oryzoides</u>	OBL
River Bulrush	<u>Scirpus fluviatilis</u>	OBL
Sedge	<u>Carex pensylvanica</u>	
Sedges	Cyperaceae	
Skunk Cabbage	<u>Symplocarpus foetidus</u>	OBL
Smartweed	<u>Polygonum</u> sp.	
Spotted Jewelweed	<u>Impatiens capensis</u>	FACW
Teaberry	<u>Gaultheria procumbens</u>	FACU
Turtlehead	<u>Chelone</u> sp.	
Tussock Sedge	<u>Scirpus stricta</u>	OBL
Wool-Grass	<u>Scirpus cyperinus</u>	OBL
Upland Grasses	Gramineae	
<u>Vines</u>		
Grape	<u>Vitis</u> sp.	

TABLE 30. (continued)

<u>Common Name</u>	<u>Latin Name</u>	<u>Wetland Indicator Status</u>
<u>Shrubs</u>		
Alder	<u>Alnus sp.</u>	
American Hazelnut	<u>Corylus americana</u>	FACU-
Arrow-wood	<u>Viburnum recognitum</u>	FACW
Bayberry	<u>Myrica pensylvanica</u>	FAC
Common Elder	<u>Sambucus canadensis</u>	FACW-
European Buckthorn	<u>Rhamnus catharticus</u>	
Highbush Blueberry	<u>Vaccinium corymbosum</u>	FACW
Huckleberry	<u>Gaylussacia sp.</u>	
Poison Sumac	<u>Toxicodendron vernix</u>	OBL
Sheep Laurel	<u>Kalmia angustifolia</u>	FAC
Swamp Azalea	<u>Rhododendron viscosum</u>	OBL
Swamp Dogwood	<u>Cornus amomum</u>	FACW
Winterberry	<u>Ilex verticillata</u>	FACW+
Witherod	<u>Viburnum cassinoides</u>	FACW
<u>Trees</u>		
American Elm	<u>Ulmus americana</u>	FAC
Black Willow	<u>Salix nigra</u>	FACW+
Choke Cherry	<u>Prunus virginiana</u>	FACU
Gray Birch	<u>Betula populifolia</u>	FAC
Quaking Aspen	<u>Populus tremula</u>	FACU
Red Maple	<u>Acer rubrum</u>	FACW
Red Oak	<u>Quercus rubra</u>	FACU-
White Oak	<u>Quercus alba</u>	FACU-
White Pine	<u>Pinus strobus</u>	FACU

NOTES:

1. Based on field observations conducted in March and September 1990.
2. Wetland indicator status from the 1988, U.S. Fish and Wildlife Service National List of Plant Species that Occur in Wetlands: Northeast (Region 1).
 - OBL = Occur almost always (>99%) under natural conditions in wetlands.
 - FACW = Usually occur in wetland (67%-99%), but occasionally found in nonwetlands.
 - FAC = Equally likely to occur in wetlands or nonwetlands (34%-66%).
 - FACU = Usually occur in nonwetlands (67%-99%), but occasionally found in wetlands (1%-33%).

TABLE 31

WILDLIFE OBSERVATIONS 60 OLYMPIA AVENUE

Wildlife or their signs were observed during a site visit in September 1990. Aquatic invertebrates were collected with a dip net from the Aberjona River, and from ponded water within wetland. Sampling locations for the aquatic invertebrates are shown on Figure 4. The aquatic invertebrates were identified by Dr. Douglas Smith, curator of the University of Massachusetts Zoology Museum. Mr. Smith was the first to describe the Mystic Valley amphipod, a species of special concern in Massachusetts. This amphipod has been collected in wetlands along the Aberjona River north of the wells G & H site.

SMALL MAMMALS

<u>Common Name</u>	<u>Latin Name</u>
Opossum	<u>Didelphis marsupialis</u>
Woodchuck	<u>Marmota monax</u>
White-tailed Deer	<u>Odocoileus virginianus borealis</u>
Gray Squirrel	<u>Sciurus carolinensis</u>
Eastern Cottontail	<u>Sylvilagus floridanus</u>

BIRDS

<u>Common Name</u>	<u>Latin Name</u>
Killdeer	<u>Charadrius vocifer</u>

AQUATIC INVERTEBRATES

<u>Common Name</u>	<u>Latin Name/Taxon</u>	<u>Stations</u>
CRUSTACEANS:		
Amphipod	<u>Crangonyx pseudogracillis</u>	1,2,5
Isopod	<u>Caecidotea communis</u>	1,2,3,5
Juvenile female crayfish	<u>Orconectes</u> sp.	1,2
MOLLUSKS:		
Pill clam	<u>Pisidium casertanum</u>	4
Freshwater orb snail	<u>Helisoma trivolis</u>	3,4,5
Freshwater orb snail	<u>Helisoma campanulatum</u> ?	4
Freshwater snail	<u>Physella gyrina</u>	3,4,5
Freshwater snail	<u>Stagnicola elodes</u>	4,5
Land snail	<u>Succinea</u> sp.	4
INSECTS:		
Darner	<u>Aeshnia</u> sp.	4
Net-spinning caddisfly	<u>Archtopsyche</u> ? sp.	5
Narrow-winged damselfly	<u>Argia</u> sp.	2
Crane fly larvae	<u>Bittacomorpha</u> sp.	6
Water strider	Gerridae	5

TABLE 31 (Continued)

AQUATIC INVERTEBRATES AT EACH SAMPLE STATION

SAMPLE 1. ("upstream" Aberjona River and equivalent to Station X-9 of Alliance Technologies)

(Crustaceans) CRUSTACEA

(Amphipod) Amphipoda - Crangonyctidae - Crangonyx pseudogracillis
(Isopod) Isopoda - Asellidae - Caecidotea communis
(Crayfish juvenile female) Cambaridae - Orconectes sp.

SAMPLE 2. ("downstream" Aberjona River and equivalent to Station X-11 of Alliance Technologies)

HEXAPODA : (Insects) INSECTA

(Narrow-winged damselfly) Odonata - Coenagrionidae - Argia sp.

(Crustaceans) CRUSTACEA

(Amphipod) Amphipoda - Crangonyctidae - Crangonyx pseudogracillis
(Isopod) Isopoda - Asellidae - Caecidotea communis
(Crayfish juvenile female) Cambaridae - Orconectes sp.

SAMPLE 3 (on-site ponded water within an area of tussock sedge south of the 60 Olympia Avenue parking lot and monitoring well S72D)

(Crustaceans) CRUSTACEA

(Isopod) Isopoda - Asellidae - Caecidotea communis

(Mollusks) MOLLUSCA : (Snails) GASTROPODA

(Freshwater snail) - Physidae - Physella gyrina
(Freshwater orb snail) - Planorbidae - Helisoma (= Planorbella)
trivolvis

SAMPLE 4 (on-site ponded water in swamp at the southeast corner of the 60 Olympia Avenue property)

HEXAPODA : (Insects) INSECTA

(Darner) Odonata - Aeshnidae - Aeshna sp.

(Mollusks) MOLLUSCA : (Clams) PELECYPODA

(Pill clam) - Sphaeridae (=Pisidiidae) - Pisidium casertanum

: (Snails) GASTROPODA

(Freshwater orb snail) - Planorbidae - Helisoma trivolis
(Freshwater snail) - Physidae - Physella gyrina
(Freshwater snail) - Limnaeidae - Stagnicola elodes
(Land snail) - Limnaeidae - Succinea sp.

TABLE 31 (Continued)

SAMPLE 5 (off-site small rivulet that flows toward the Aberjona River located off the property east of the 60 Olympia Avenue parking lot)

HEXAPODA : (Insects) INSECTA

(Net-spinning Caddisfly) Trichoptera - Hydropsychidae -
Archtopsyche ? sp.
(Water Strider) Hemiptera - Gerridae

(Crustaceans) CRUSTACEA

(Amphipod) Amphipoda - Crangonyctidae - Crangonyx pseudogracillis
(Isopod) Isopoda - Asellidae - Caecidotea communis
(Freshwater orb snail) - Planorbidae - Helisoma (=Planorbella)
trivolis and H. campanulatum
(Freshwater snail) - Physidae - Physella gyrina
(Freshwater snail) - Limnaeidae - Stagnicola elodes

SAMPLE 6 (off-site small pool within red maple swamp east of the 60 Olympia Avenue property)

HEXAPODA : (Insects) INSECTA

(Crane Fly larvae) - Ptychopteridae - Bittacomorpha sp.

TABLE 32

FISH SPECIES IN THE ABERJONA RIVER BASIN¹

<u>Common Name</u>	<u>Scientific Name</u>
Alewife	<u>Alosa pseudoharagus</u>
Pumpkinseed	<u>Lepomis gibbosus</u>
Bluegill	<u>Lepomis machrochirus</u>
American Eel	<u>Anguilla rostrata</u>
Yellow Perch	<u>Perca flavescens</u>
Goldfish	<u>Carassius auratus</u>
Golden Shiner	<u>Notemigonus crysoleucas</u>
Brown Bullhead	<u>Ictalurus nebulosus</u>
White Perch	<u>Morone americana</u>
Largemouth Bass	<u>Micropterus salmoides</u>
Swamp Darter	Percidae family
Chain Pickerel	<u>Esox niger</u>
Common Carp	<u>Cyprinus carpio</u>

Notes:

1. Source: Massachusetts Division of Fisheries and Wildlife (DFW)
2. DFW representative expressed doubt that any of these species reside in the Aberjona River. No fish were observed in GZA's or Alliance Technologies' limited investigations of the Aberjona River near the 60 Olympia Avenue facility.

TABLE 33

COMPARISON OF PREDICTED SURFACE WATER CONCENTRATIONS TO
USEPA AMBIENT WATER QUALITY CRITERIA FOR THE PROTECTION
OF AQUATIC LIFE IN THE ABERJONA RIVER

COMPOUND	PREDICTED	CHRONIC LOEL	FRESHWATER AWQC	CHRONIC	HAZARD INDICES
	SURFACE WATER CONCENTRATIONS (ug/l)		ACUTE LOEL (ug/l)		ACUTE (ug/l)
VOLATILE ORGANICS (VOCs)					
Aromatics:					
Benzene	0.022	NA	5,300	NA	4.2E-06
Ethylbenzene	0.0021	NA	32,000	NA	6.6E-08
Toluene	0.0071	NA	17,500	NA	4.1E-07
Xylenes (total)	0.0068	NA	NA	NA	NA
N-Butylbenzene	0.002	NA	NA	NA	NA
sec-Butylbenzene	0.0018	NA	NA	NA	NA
tert-Butylbenzene	0.0018	NA	NA	NA	NA
Isopropylbenzene	0.0022	NA	NA	NA	NA
P-Isopropylbenzene	0.0018	NA	NA	NA	NA
Naphthalene	0.0029	620	2,300	4.7E-06	1.3E-06
N-Propylbenzene	0.0022	NA	NA	NA	NA
1,2,4-Trimethylbenzene	0.0024	NA	NA	NA	NA
1,3,5-Trimethylbenzene	0.0024	NA	NA	NA	NA
Chlorinated:					
Chloroform	0.0023	1,240	28,900	1.9E-06	8.0E-08
1,1-Dichloroethane	0.0023	NA	NA	1.2E-07	2.0E-08
1,2-Dichloroethane	0.0018	NA	NA	9.0E-08	1.5E-08
1,1-Dichloroethene	0.002	NA	11,600 (4)	NA	1.7E-07
cis-1,2-Dichloroethene	0.011	NA	11,600 (4)	NA	9.5E-07
trans-1,2-Dichloroethene	0.0022	NA	11,600 (4)	NA	1.9E-07
Tetrachloroethene	0.0066	840	5,280	7.9E-06	1.2E-06
1,2,4-Trichlorobenzene	0.002	NA	NA	NA	NA
Trichloroethene	0.0046	21,900	45,000	2.1E-07	1.0E-07
1,1,2-Trichloroethane	0.0019	9,400 (5)	18,000 (5)	2.0E-07	1.1E-07
Vinyl Chloride	0.0019	NA	NA	NA	NA

NOTES:

1. U.S. EPA Ambient Water Quality Criteria obtained from: Quality Criteria for Water, 1986. United States Environmental Protection Agency, Office of Water, Regulations and Standards, Washington D.C. EPA 440/5-86-001.
2. LOEL - Lowest Observable Effect Level.
3. NA = No EPA Criteria are available
4. The U.S. EPA designated Acute LOEL for "Dichloroethenes."
5. The U.S. EPA designated Acute and Chronic LOELs for "Trichlorinated Ethanes."
6. The U.S. EPA designated Acute and Chronic LOELs for "Dichlorinated Ethanes"
7. Predicted surface water concentrations were calculated by dividing the arithmetic mean of the detected concentrations of a compound in groundwater by a dilution factor of 250 (assumed low flow in the Aberjona River).
8. Hazard indices are calculated by dividing the predicted surface water concentration of a compound by the U.S. EPA Ambient Water Quality Criteria.

TABLE 34
SEDIMENT HAZARD INDICES FOR SEMI-VOLATILE ORGANICS
IN THE ABERJONA RIVER SEDIMENT
60 OLYMPIA AVENUE

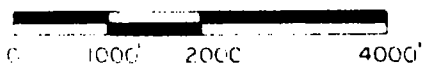
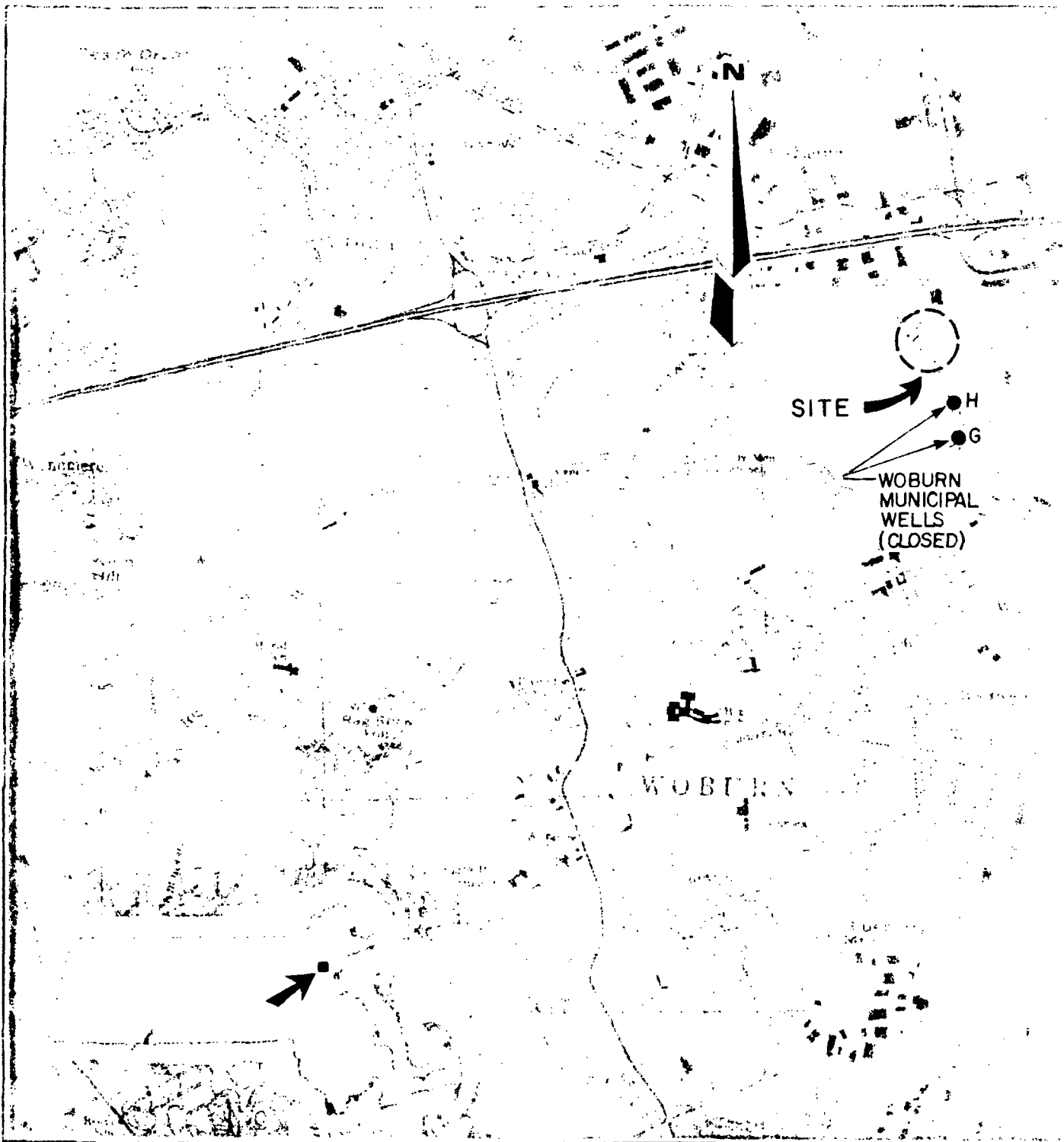
COMPOUND	SEDIMENT QUALITY CRITERIA HAZARD INDEX (SD-03/SQC)	NOAA EFFECTS RANGE LOW HAZARD INDEX (SD-03/ER-L)
<u>Phthalates:</u>		
Bis(2-ethylhexyl) phthalate	1.6 E-03	NA
<u>Polynuclear aromatics:</u>		
Acenaphthene	1.2 E-02	0.6
Anthracene	1.4 E-02	2.2
Benzo(a)anthracene	5.5 E-02	3.1
Benzo(b)fluoranthene	5.5 E-02	NA
Benzo(k)fluoranthene	5.7 E-05	NA
Benzo(g,h,i)perylene	4.8 E-03	NA
Benzo(a)pyrene	6.3 E-02	1.7
Chrysene	4.5 E-01	2.4
Dibenz(a,h)anthracene	2.6 E-02	2.1
Fluoranthene	8.8 E-02	2.8
Indeno(1,2,3-cd)pyrene	2.1 E-03	NA
Phenanthrene	6.6 E-01	4.0
Pyrene	10.4 E-02	3.9
TOTAL PAH	NA	2.2

Notes:

- Hazard indices were calculated by dividing the concentration of a compound in Ebasco Services sediment sample SD-03 from the Aberjona River adjacent to 60 Olympia Avenue by the Sediment Quality Criteria (SQC) modified from Ebasco Services (1988) and the NOAA Effects Range-Low (ER-L) value, respectively.
- NA = not available because of lack of criteria or effects levels.

FIGURES

FILE No. 4596.2 © 1991 GZA GEOENVIRONMENTAL, INC.



SOURCE: USGS LEXINGTON, MASS. (1971)
AND WILMINGTON, MASS. (1979)
QUADRANGLE MAPS



GZA
GeoEnvironmental, Inc.

PHASE II SITE INVESTIGATION

60 OLYMPIA AVENUE
WOBURN, MASS.

LOCUS PLAN

JULY 1991

FIGURE No. 1

AND 1/88.



MONITORING WELLS INSTALLED BY GZA DRILLING, INC DEC 1989-JAN 1990.

PHASE II SITE INVESTIGATION

SITE UTILITIES
AND EXPLORATION
LOCATION PLAN

JULY 1991

NOTES:

- 1) BASE MAP DERIVED FROM DATA PROVIDED BY JUNIPER ELEVATION CORP. ENTITLED "BETHUNDA AREA COASTAL HAZARD" DATED 3, 25, 87, ORIGINAL SCALE 1"=40'.
- 2) THE LOCATION OF THE ELEVATIONS WERE APPROXIMATELY DETERMINED BY TAPE MEASUREMENTS AND "LINE OF SIGHT" FROM EXISTING TOPOGRAPHIC FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
- 3) REFER TO FIGURE NO. 2 FOR ADDITIONAL INFORMATION.

LEGEND:

- 1 APPROXIMATE LOCATION OF 1,000 GALLON UNDERGROUND WASTE OIL STORAGE TANK
- 2 APPROXIMATE LOCATION OF (4) FORMER UNDERGROUND PETROLEUM FUEL STORAGE TANKS
- MONITORING WELL INSTALLED BY GZA DRILLING, INC. ON 1/8 AND 1/9/85 AND REFERENCED IN ATTACHED TEXT. LOCATIONS OF ADDITIONAL WELLS NOT SPECIFICALLY REFERENCED IN TEXT ARE INDICATED WITH DOTS.
- 6 ASSUMED ON-SITE BENCHMARK, EDGE OF MAIN CONC. FLOOR SLAB, DATUM ELEVATION OF 100.00 FEET
- SOIL GAS MONITORING LOCATION BY GZA, JULY 13-14, 1989

PHASE II SITE ASSESSMENT
60 OLYMPIA AVENUE
WEBURN, MASS.

SOIL GAS MONITORING POINT
LOCATION PLAN

SEPT. 1989

FIGURE NO. 3

NOTES:

- 1) BASE MAP DERIVED FROM PLANIMETRIC MAP BY JUNIPER DEVELOPMENT CORP. ENTITLED "DETAILED PLANIMETRIC MAP" DATED 10/25/83, ORIGINAL SCALE 1"=40'.
- 2) THE LOCATIONS OF THE EXPLORATIONS WERE APPROXIMATELY DETERMINED BY TAPE MEASUREMENTS AND "LINE OF SIGHT" FROM EXISTING TOPOGRAPHIC FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
- 3) REFER TO FIGURE NO. 2 FOR ADDITIONAL INFORMATION.

LEGEND



SS-1

▲ SW-1

PHASE II SITE ASSESSMENT
60 OLYMPIA AVENUE
WOBBURN, MASS

WETLAND SAMPLING
PLAN


JULY 3, 1991

FIGURE II 4

- 2) GROUNDWATER CONTOURS ARE BASED ON DATA FROM WIDELY SPACED EXPLORATIONS AND MAY NOT REFLECT ACTUAL SUBSURFACE CONDITIONS.
- 3) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT THE TIMES AND UNDER CONDITIONS STATED ON THE LOGS. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TEMPERATURE AND OTHER FACTORS AT THE TIME MEASUREMENTS WERE MADE.
- 4) REFER TO FIGURE NO. 2 FOR ADDITIONAL NOTES AND LEGEND.
- 5) DUE TO THE PRESENCE OF FLOATING PETROLEUM PRODUCT, GROUNDWATER ELEVATIONS WERE NOT CALCULATED FOR WELL MW-1.

LEGEND:

 9336-GROUNDWATER LEVEL, 3/26/90.

 GROUNDWATER CONTOUR
94.5

1991 G7A GROUNDWATER INVESTIGATION, INC.

2

PHASE II SITE INVESTIGATION

OF POLYMERIZATION UNIT

WELLS, MAINE

GROUNDWATER CONTOUR
PLAN

JULY 1991

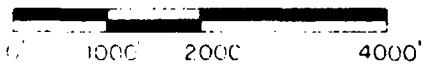
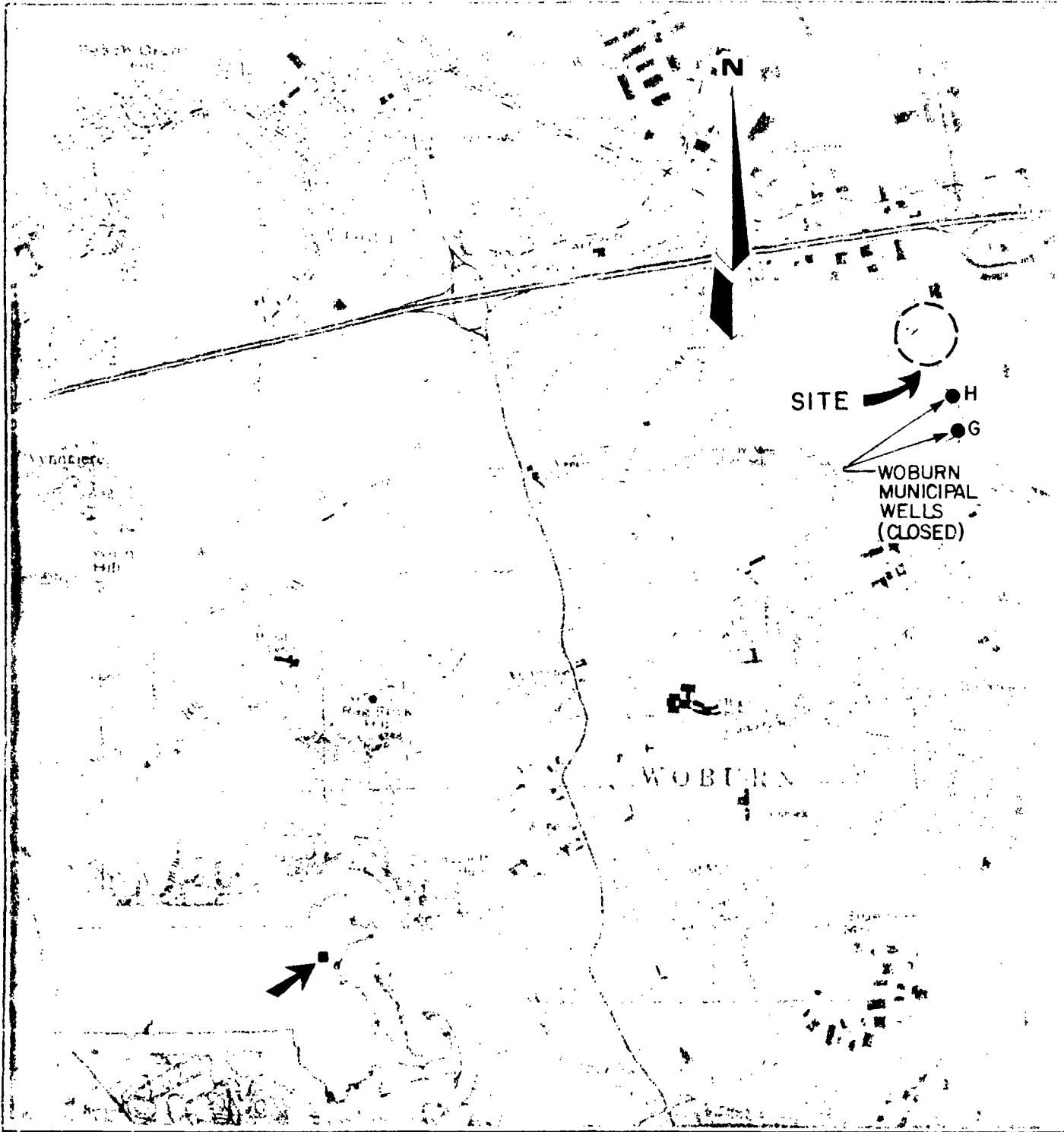
FIGURE 5

LEGEND:

FIGURES

1991 GZA GEOENVIRONMENTAL, INC.

FILE No. 4596.2



SOURCE: USGS LEXINGTON, MASS. (1971)
AND WILMINGTON, MASS. (1979)
QUADRANGLE MAPS



GZA
GeoEnvironmental, Inc.

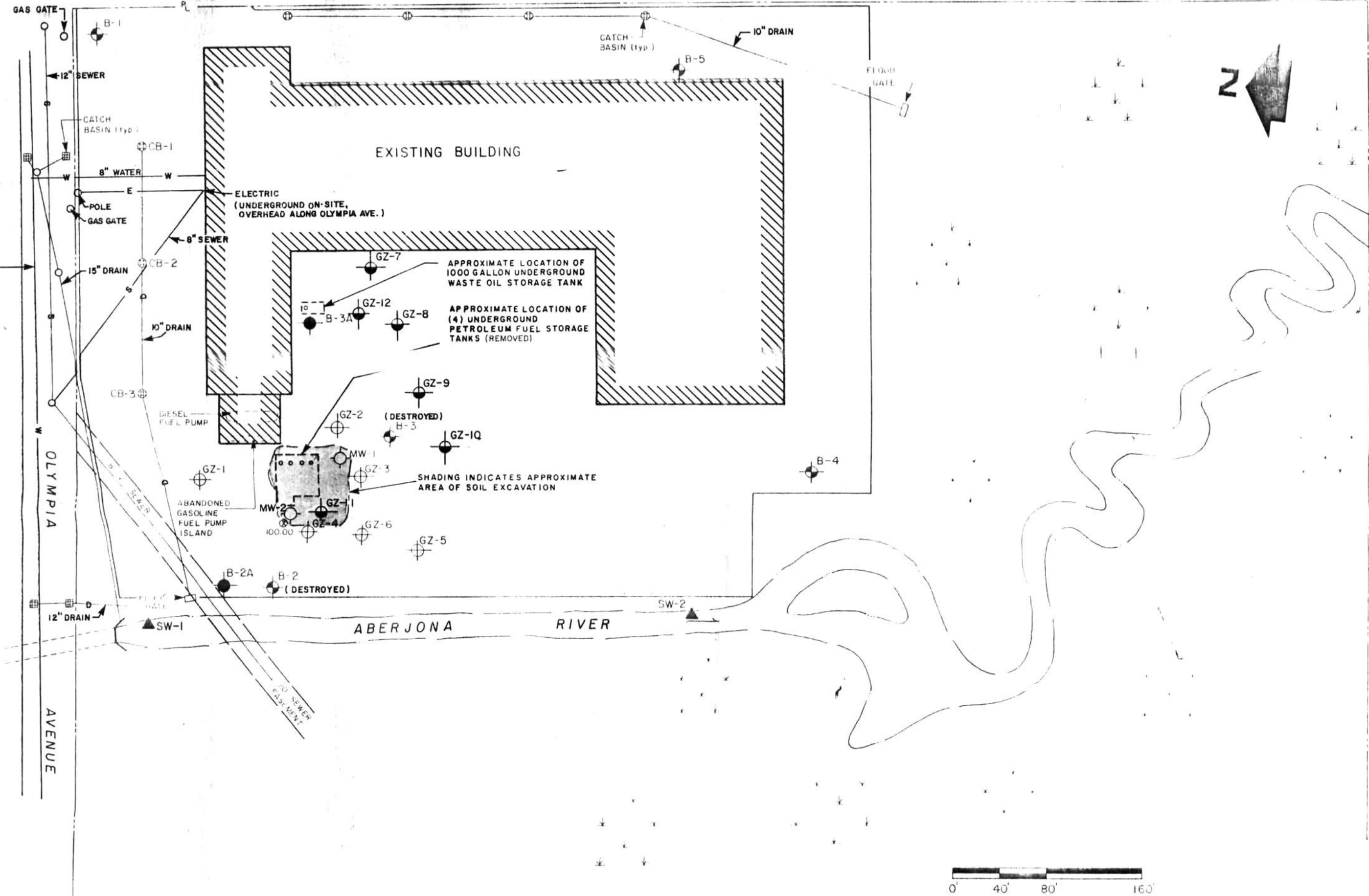
PHASE II SITE INVESTIGATION

60 OLYMPIA AVENUE
WOBURN, MASS.

LOCUS PLAN

JULY 1991

FIGURE No. 1

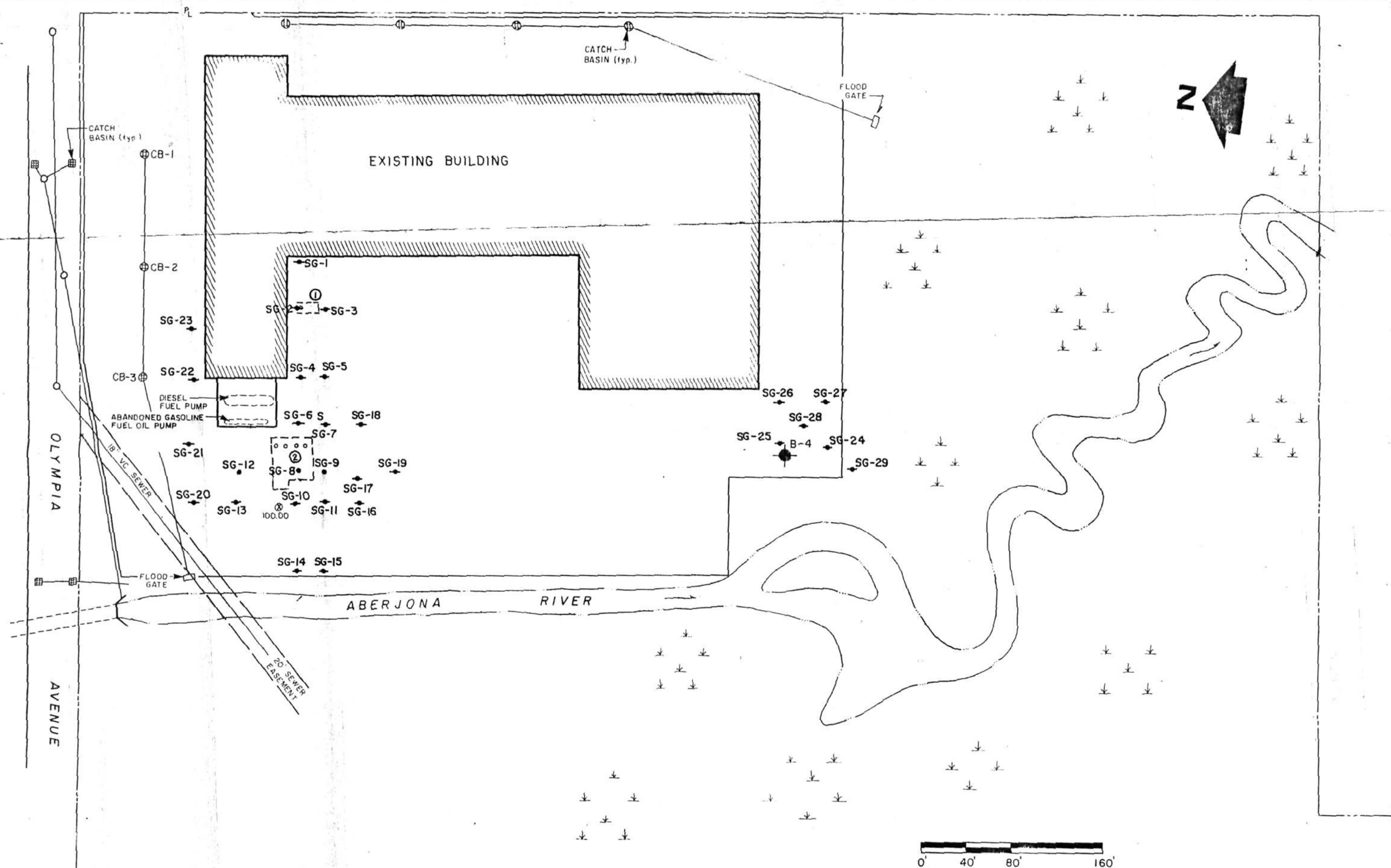


NOTES:

- 1) BASE MAP DEVELOPED FROM PLAN PROVIDED BY JUNIPER DEVELOPMENT CORP. ENTITLED "DETAIL PLAN WOBURN, MASS." DATED 5/25/83, ORIGINAL SCALE 1" = 40'
- 2) THE LOCATIONS OF THE BORINGS WERE APPROXIMATELY DETERMINED BY TAPE MEASUREMENTS AND "LINE OF SIGHT" FROM EXISTING TOPOGRAPHIC FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.

LEGEND:

- MONITORING WELLS INSTALLED BY GZA DRILLING, INC. ON 4/8/88
- MONITORING WELLS INSTALLED BY HILDE-EYSTER TECHNICAL SERVICES, INC. OF ACCORD, MASS. IN JUNE, 1987
- MONITORING WELLS INSTALLED BY GZA DRILLING, INC. ON 1/8 AND 1/9/85
- ASSUMED ON SITE BENCHMARK, ESTABLISHED BY GZA DRILLING, INC. DATUM ELEVATION OF 100.00 FEET
- SURFACE WATER SAMPLES COLLECTED BY GZA PERSONNEL ON 6/5/88 AND 1/88.
- MONITORING WELLS LOCATED ON SITE. INSTALLATION DETAILS NOT AVAILABLE
- MONITORING WELLS INSTALLED BY GZA DRILLING, INC. DEC 1989-JAN 1990.

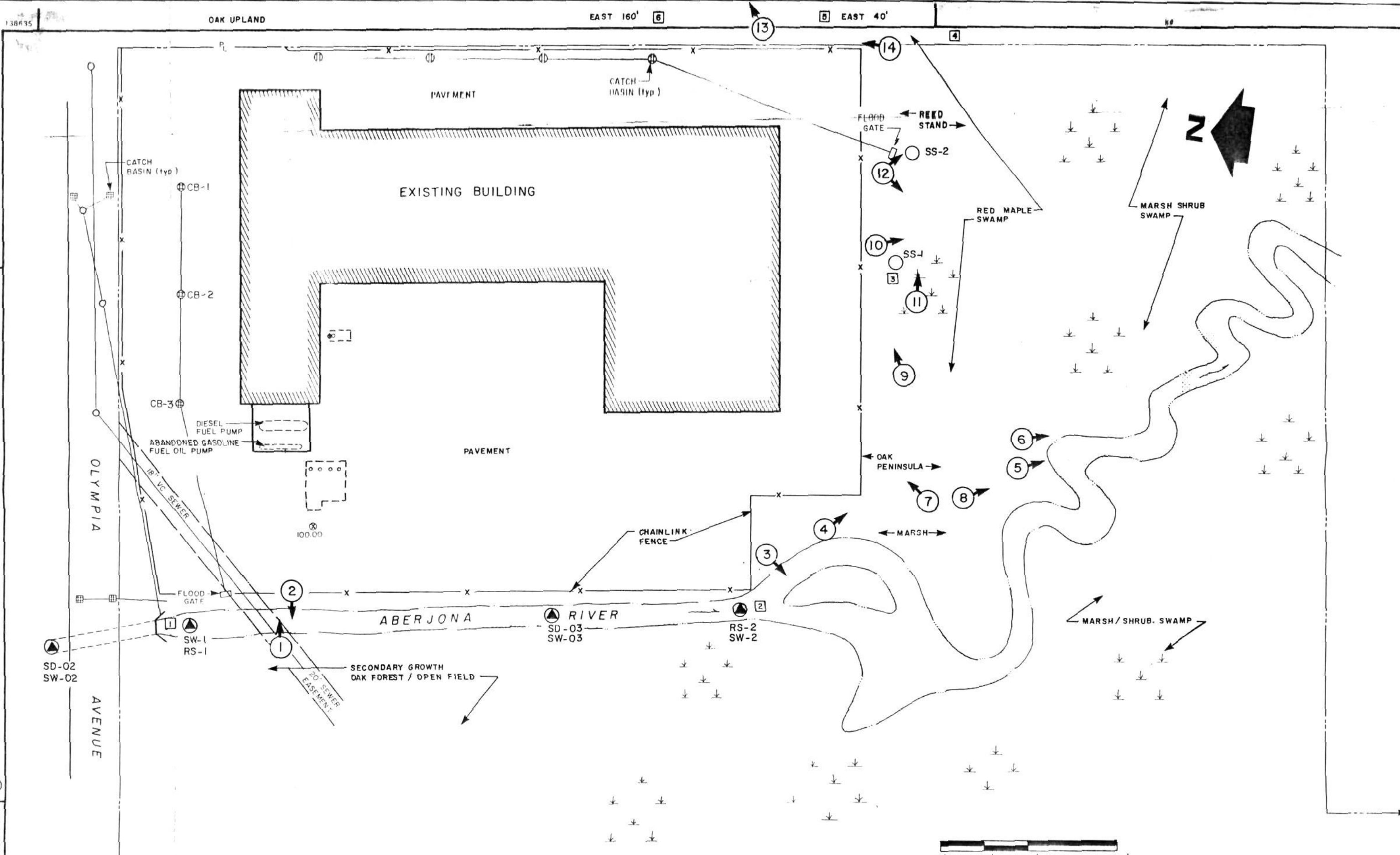


NOTES:

- 1) BASE MAP DEVELOPED FROM PLAN PROVIDED BY JUNIPER DEVELOPMENT CORP. ENTITLED "DETAIL PLAN - WOBURN, MASS." DATED 5/25/83, ORIGINAL SCALE 1:
- 2) THE LOCATIONS OF THE EXPLORATIONS WERE APPROXIMATELY DETERMINED BY TA MEASUREMENTS AND "LINE OF SIGHT" FROM EXISTING TOPOGRAPHIC FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED THE METHOD USED.
- 3) REFER TO FIGURE No. 2 FOR ADDITIONAL INFORMATION.

LEGEND:

- ① APPROXIMATE LOCATION OF 1,000 GALLON UNDERGROUND WASTE OIL STORAGE TANK
- ② APPROXIMATE LOCATION OF (4) FORMER UNDERGROUND PETROLEUM FUEL STORAGE TANKS
- MONITORING WELL INSTALLED BY GZA DRILLING, INC. ON 1/8 AND 1/9/85 AND REFERENCED IN ATTACHED TEXT. LOCATIONS OF ADDITIONAL WELLS NOT SPECIFICALLY REFERENCED IN TEXT ARE INDICATED ON FIGURE 4.
- ⊗ ASSUMED ON-SITE BENCHMARK, EDGE OF MW-2 CONCRETE PAD, DATUM ELEVATION OF 100.00 FEET
- SOIL GAS MONITORING LOCATION BY GZA, JULY 13-14, 1989



NOTES:

- 1) BASE MAP DEVELOPED FROM PLAN PROVIDED BY JUNIPER DEVELOPMENT CORP. ENTITLED "DETAIL PLAN - WOBURN, MASS." DATED 5/25/83, ORIGINAL SCALE 1"=40'.
- 2) THE LOCATIONS OF THE EXPLORATIONS WERE APPROXIMATELY DETERMINED BY TAPE MEASUREMENTS AND "LINE OF SIGHT" FROM EXISTING TOPOGRAPHIC FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
- 3) REFER TO FIGURE No. 2 FOR ADDITIONAL INFORMATION.

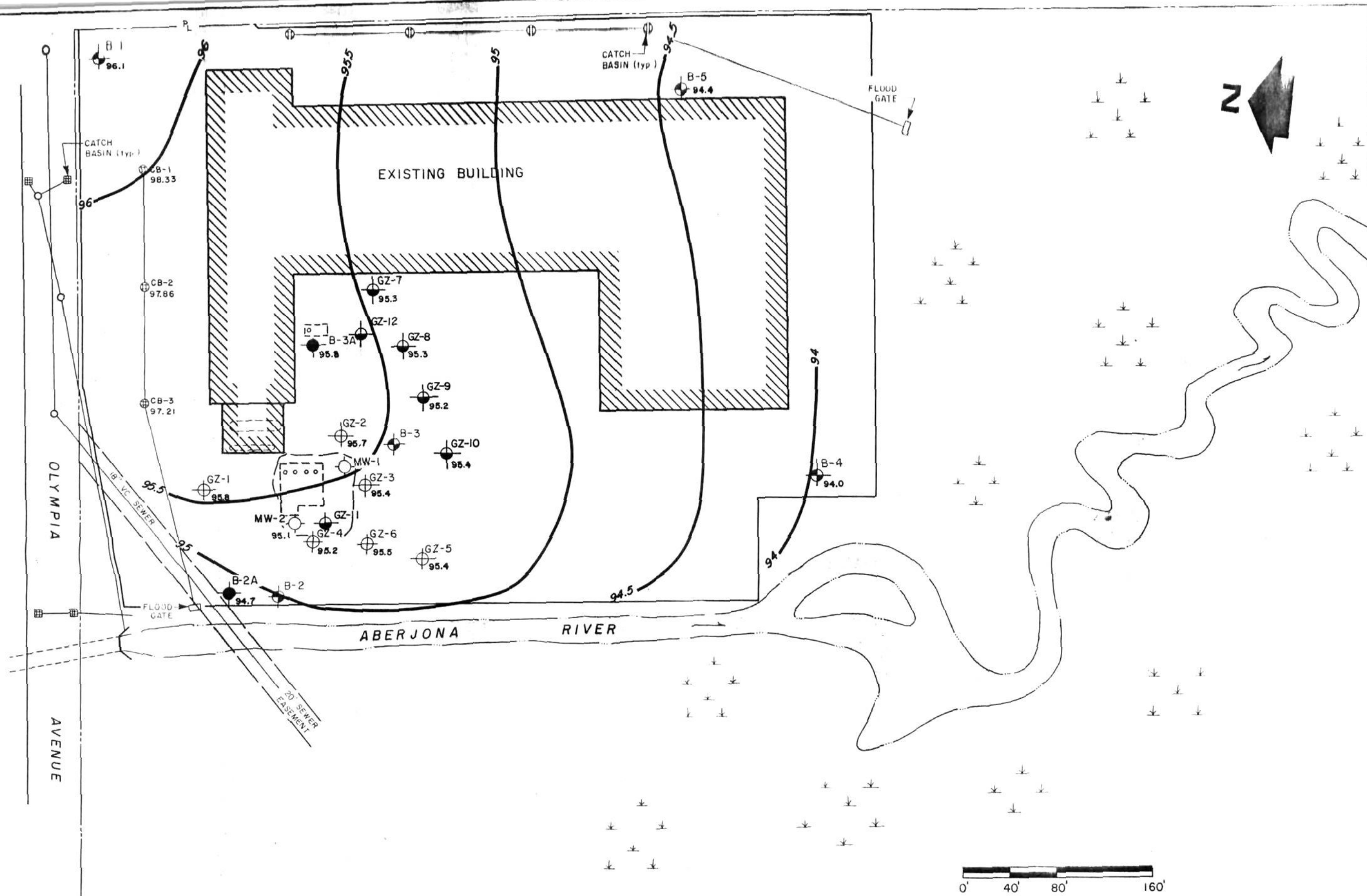
LEGEND:

- 12 PHOTOGRAPH LOCATION AND DIRECTION
- SS-1 SURFICIAL SOIL / SEDIMENT SAMPLE LOCATION.
GZA SOIL SAMPLES SS-1 AND SS-2 IN WETLAND.
GZA SEDIMENT SAMPLES RS-1 AND RS-2 IN THE ABERJONA RIVER.
EBASCO SEDIMENT SAMPLES SD-02 AND SD-03 IN THE ABERJONA RIVER.
- SW-1 SURFACE WATER SAMPLE LOCATION.
GZA SURFACE WATER SAMPLES SW-1 AND SW-2 IN THE ABERJONA RIVER.
EBASCO SURFACE WATER SAMPLES SW-02 AND SW-03.
- 3 GZA DIP NET SAMPLE LOCATIONS FOR AQUATIC INVERTEBRATES.
NOTE: LOCATIONS 1 AND 2 ARE EQUIVALENT TO DIP NET LOCATIONS X-9 AND X-1 RESPECTIVELY, OF ALLIANCE TECHNOLOGY (1987).

PHASE II SITE ASSESSMENT
60 OLYMPIA AVENUE
WOBURN, MASS.

WETLAND SAMPLING
PLAN
JULY 3, 1991

FIGURE No.



NOTES:

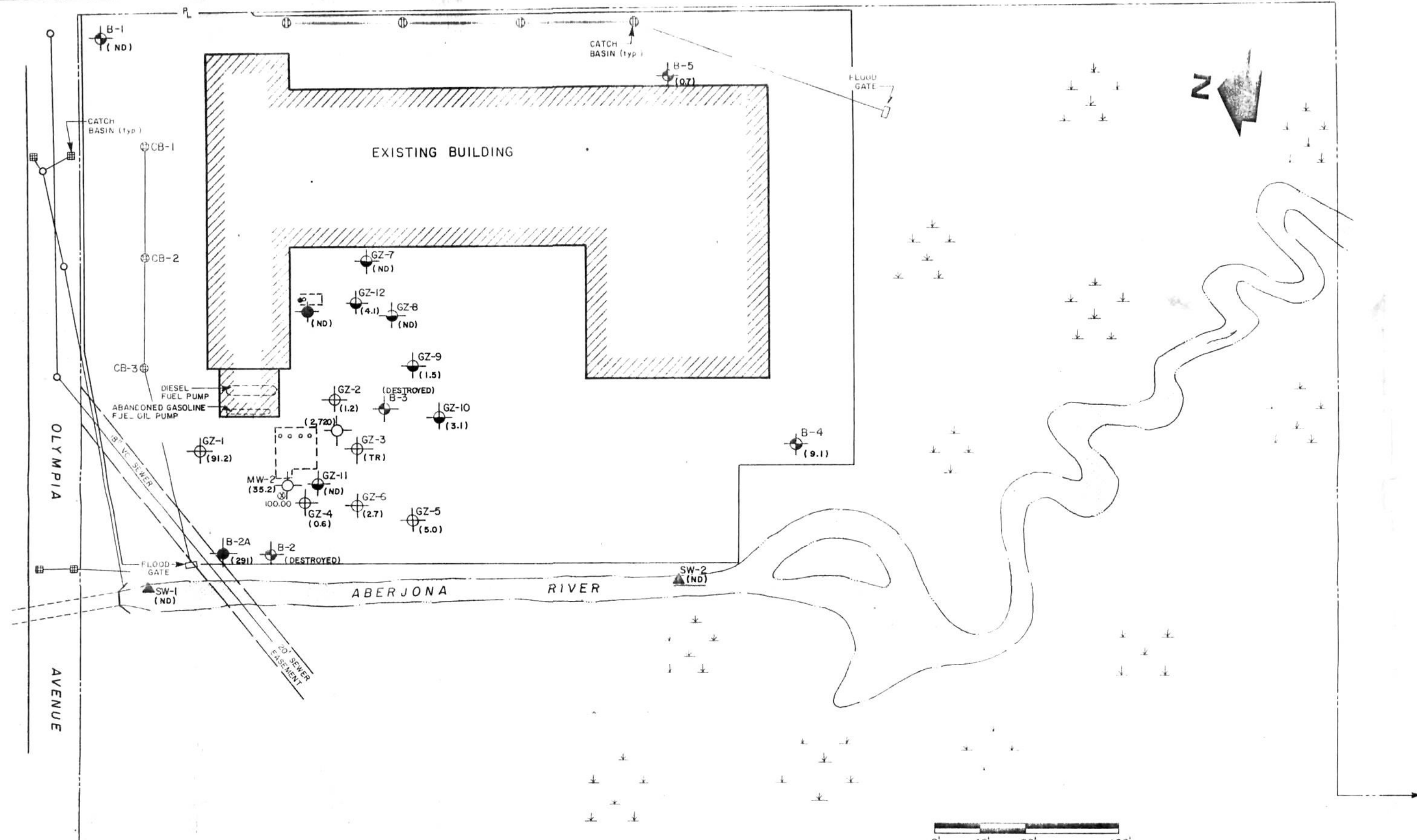
- 1) BASE MAP DEVELOPED FROM PLAN PROVIDED BY JUNIPER DEVELOPMENT CORP. ENTITLED "DETAIL PLAN WOBURN, MASS." DATED 5/25/83, ORIGINAL SCALE: 1" = 40'.
- 2) GROUNDWATER CONTOURS ARE BASED ON DATA FROM WIDELY SPACED EXPLORATIONS AND MAY NOT REFLECT ACTUAL SUBSURFACE CONDITIONS.
- 3) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT THE TIMES AND UNDER CONDITIONS STATED ON THE LOGS. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TEMPERATURE AND OTHER FACTORS AT THE TIME MEASUREMENTS WERE MADE.
- 4) REFER TO FIGURE No. 2 FOR ADDITIONAL NOTES AND LEGEND.
- 5) DUE TO THE PRESENCE OF FLOATING PETROLEUM PRODUCT, GROUNDWATER ELEVATIONS WERE NOT CALCULATED FOR WELL MW-1.

LEGEND:

- 93.36—GROUNDWATER LEVEL, 3/26/90.
- GROUNDWATER CONTOUR

PROPERTY LINE
EXTENDS 640'

<p>PHASE II SITE INVESTIGATION 60 OLYMPIA AVENUE WOBURN, MASS.</p>	<p>GROUNDWATER CONTOUR PLAN</p>
<p>JULY 1991</p>	<p>FIGURE No.5</p>



NOTES:

- 1) REFER TO FIGURE No.2 FOR ADDITIONAL NOTES & LEGEND.

LEGEND:

- (291) TOTAL CONCENTRATION OF BENZENE, TOLUENE, ETHYL BENZENE, AND XYLENES (BTEX COMPOUNDS) IN SAMPLE COLLECTED JAN 1990. RESULTS IN PARTS PER BILLION (ppb).
- (ND) NONE DETECTED
- (TR) TRACE (REFER TO LABORATORY REPORT)

